ECODYNAMICS SERIES NO. 72-1

ECOLOGY STUDIES IN WESTERN UTAH

1971

ANNUAL REPORT

by

EcoDynamics, Inc.
82 West Louise Avenue
Salt Lake City, Utah

May 31, 1972

Research Sponsored by Deseret Test Center Department of Army
Contract No. DAAD-09-70-C-0051

Ecology Studies in Western Utah

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FOREWORD

The purpose of this report is to furnish data accrued from a one-year disease surveillance and ecological investigation in the Great Salt Lake Desert region of western Utah. From a cumulative comparison and analysis of similar preceding data, background levels and nidality of endemic diseases become increasingly clear. Certain basic collecting and disgnostic factors have been compared in this document over a five year period.

In conducting the research described in this report, the investigator(s) adhered to the "Guide for Laboratory Animal Facilities and Care," as promulgated by the Committee on the Guide for Laboratory Animal Resources, National Academy of Sciences-National Research Council.

ECODYNAMICS, INC. ORGANIZATION

FOR

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DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author)	2a. REPORT SECURITY CLASSIFICATION
EcoDynamics, Inc. 82 West Louise Avenue, Salt Lake City, Utah 84115	Unclassified
	2b. GROUP

3. REPORT TITLE

ECOLOGY STUDIES IN WESTERN UTAH

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Annual Report (1 January 1971 through 31 December 1971)

5. AUTHOR(S) (First name, middle initial, last name)

Staff, EcoDynamics, Inc. (Peter F. Olsen, Ph.D.)

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
31 May 1972	112	0

8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S)
DAAD-09-70-C-0051	EcoDynamics Series No. 72-1
b. PROJECT NO. IX665704DL12-02	
c. AMCMS - Code No. 565C.12.L1200	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
d.	

10. DISTRIBUTION STATEMENT

Approved for public release; distributuion unlimited

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	U.S. Army, Deseret Test Center Fort Douglas, Utah 84113

13. ABSTRACT

An extensive survey of zoonotic diseases was conducted in the desert region of western Utah. Native mammals, birds and bloodsucking vectors were tested for evidence of tularemia, plague, Q fever and Rocky Mountain spotted fever. Positive findings were correlated with ecological parameters. Two epidemics of human tularemia were investigated.

Ecological investigations of the native fauna were also conducted with primary emphasis on lagomorphs and rodents. Various aspects of their ecology were studied including basic breeding biology, habitat relationships, population fluctuations, population density, age structure and general population dynamics.

A breeding colony of native rodents was maintained.

IA

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Tularemia, Francisella tularensis						
Plague, Yersinia pestis						
Q fever, Coxiella burnetii						
Rocky Mountain spotted fever Rickettsia rickettsii						
Zoonoses						
Rodents						
Lagomorphs						
Rabbits						
Carnivores						
Ectoparasites						
Fleas						
Ticks						
Tabanids						
Ecology						
Epizootiology						
Epidemiology						
Biology						
Population dynamics						
Disease						
Cattle						
Sheep						
Complement fixation test						
Agglutination tests						
Passive hemagglutination test						
Host-parasite relationships						
Utah						
Great Salt Lake Desert						
Animal rearing						
Serology						

I B

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ABSTRACT

SURVEY OF ZOONOTIC DISEASES

Specimens Collected for Disease Diagnosis

During 1971, a total of 4,316 wild vertebrates was collected from the study areas and processed for disease analysis by isolation and serological techniques. Included were 3,186 rodents, 1,062 lagomorphs, and 68 other mammals. In addition 8,047 ectoparasites associated with these animals were also collected and tested; this total was made up of 5,852 ticks and 2,195 fleas. Also tested were 2,422 deerflies. Livestock serum samples, 1,684 from sheep and 225 from cattle, collected by the government from the study area, were tested serologically. Host-parasite relationships of ticks and fleas resulting from these collections are discussed.

Results of Disease Ecology Investigations

Francisella tularensis (Tularemia)

Evidence of F. tularensis obtained by standard diagnostic methods included five isolations of the organism from the following sources: jack rabbit tissues, cottontail tissues, ticks from jack rabbits, and two from deer flies. Antibodies against F. tularensis antigen in the tube agglutination test were detected in two badgers and 13 cottontails, as well as in 2.2% of cattle and 4.3% of sheep samples.

Two human epidemics of tularemia, one involving 7 persons in the Grantsville area and another involving 16 persons in the Delta area were investigated. In the former, F. tularensis had been isolated from jack rabbits in the immediate area two months prior to the outbreak. Investigation led to the conclusion that either biting gnats (Culicoides sp. and Leptoconops sp.) or mosquitoes were the vectors which carried the infection to humans. Neither of these arthropods had previously been incriminated in tularemia epidemiology in the U.S. The Delta cases were classic in symtomology and epidemiology with the deer fly Chrysops discalis being the vector. Isolations of the organism from these flies was made at the exact site and 8 days following one of the cases. At the site of three other Delta cases, 13 or 33.3% of 39 cottontails collected showed significant antibody titers against F. tularensis in the tube agglutination test. Epidemiolcgic and epizootiologic investigations of both epidemics are detailed.

The unusual finding of 13 seropositive cottontails (only two had previously been reported in the literature) prompted extensive laboratory studies employing these animals and strains of the organism isolated from the Delta area in an effort to explain the apparent contradiction that exposure to this organism is uniformly fatal for cottontails. It was shown that all Delta strains isolated were of full virulence and that Delta cottontails did not possess any innate resistance to the organism with less than two organisms killing all cottontails exposed. It was

also shown that the antibodies detected in the wild cottontails were specific for F. tularensis and were protective. A tentative conclusion was reached that both fully virulent and avirulent strains of the organism were circulating in the population and that it was the latter which were responsible for inducing the antibodies detected.

The bacterial hemagglutination test was performed on 238 serum samples collected from carnivores in the study area from 1965 through 1971 and compared for sensitivity with the tube agglutination results previously obtained from the same samples. It was shown that the hemagglutination test is much more sensitive in detecting previous exposure to F. tularensis among carnivores than is the tube agglutination test. Incidence rates of reactors were significantly higher in badgers, coyotes, kit foxes, and bobcats. In the total carnivore sample from the seven years, 23 reactors were detected in the tube agglutination test whereas in the hemagglutination test each of these 23 plus an additional 72 were discovered. These findings indicate that tularemia activity is much more widespread geographically and much more prevalent than has been indicated by the results of previous serological surveys.

Yersinia pestis (Plague)

The only evidence of plague activity obtained by routine diagnostic methods was the isolation of Y. pestis from Monopsyllus eumolpi fleas hosted by Eutamias minimus chipmunks collected in September at Bryce Canyon National Park. Similar evidence from this same host-ectoparasite association at Bryce has been obtained several times in previous years.

The same 238 carnivore serum samples collected from 1965 through 1971 which were tested by the hemagglutination test for tularemia were also tested by the passive hamagglutination test for evidence of plague activity by the Center for Disease Control, U.S. Public Health Service, Ft. Collins, Colorado. None of these were reactors in the complement fixation test for plague. Fifteen, including five bobcats, five coyotes, three kit foxes and two badgers, were positive in the passive hemagglutination test. Results of this test, which has long been considered more sensitive for plague detection than the complement fixation test, indicated that plague activity, like tularemia activity, is much more prevalent and widespread than previously thought.

Coxiella burnetii (Q fever)

Evidence of Q fever activity in wildlife samples consisted of four serological reactors in the complement fixation test consisting of one deer mouse, one least chipmunk and two jack rabbits. No reactors were found among sheep or cattle serum samples tested. Detectable activity of C. burnetii has declined drastically since the epizootic proportions reached during 1960 but has been at the same low level since 1966, indicating that the disease is enzootic and widespread throughout the study area.

Rickettsia rickettsii (Rocky Mountain spotted fever)

Serological reactors in the complement fixation test against soluble R. rickettsii group antigen consisted of 270 jack rabbits, 15 rodents of four species, three cottontails and one cattle sample. The incidence of serological reactors among all rodent species was lower than found during 1970, significantly so among the Ord kangaroo rats and white-tailed antelope squirrels. The reactor rate in locally collected jack rabbits was 34.4%, a significant reduction from the 40.2% rate found during 1970. This was the first reversal of an upward trend in the percentage of jack rabbit reactors which commenced in 1968. Various correlations between the seropositive animals and such factors as age, time of collection, geographic area, etc., were made as well as relationships of antibody titer with age, season, and area.

IMPROVEMENT OF DIAGNOSTIC TECHNIQUES

Three major improvments in diagnostic techniques were investigated and evaluated. These included the hemagglutination test for F. tularensis, the passive hemagglutination test for Y. pestis, and the hemolymph test for the detection of R. rickettsii or related rickettsiae in ticks. The first two of these are discussed in the tularemia and plague sections of this report. Details of the hemolymph test are summarized here. It is noted that this test holds much promise as a necessary step in the eventual isolation of the R. rickettsii-like organism responsible for the large number of serological reactors in the complement fixation test.

ECOLOGICAL INVESTIGATIONS OF THE NATIVE FAUNA

Jack Rabbit Ecology and Population Dynamics

Jack rabbit populations continued to increase, although at a slower rate than noted during the last two years, continuing the trend upward from the low point reached early in 1967. On the basis of the number of rabbits seen per mile while hunting, the 1971 annual index of 5.0 per mile was 7.1 times greater than the 1967 index and 1.2 times that of 1970. Data collected from flush transects run twice annually indicated populations 1.2 times greater in March and in August of 1971 than during the corresponding months of 1970.

Data based on the examination of nearly 800 jack rabbits collected during 1971 yielded information regarding reproductive performance and population welfare. Total breeding season production per female was calculated at 8.27 young, down slightly from the 1970 figure of 9.14 young per female. A higher survival rate of young experienced in 1971 was apparently offset by the lower production per female and resulted only in a modest population growth on a par with that noted during 1970. Other facets of jack rabbit biology were investigated and reported upon including demographic analyses of general population dynamics.

Rodent Ecology and Population Dynamics

The relative density of rodent populations, based on the trap-night index or trapping success, was determined and compared with similar figures for previous years. Overall, on the basis of more than 34,000 trap-nights and more than 3,600 captures, trapping efforts produced one rodent in 9.4 trap-nights or 10.6% trapping success. Following the low of 7.0% success in 1967, trapping success rose sharply in 1968 to 20.9%, declined slightly to 19.9% during 1969, and continued downward in 1970 and 1971. The reasons for this decline are explored.

Data based on nearly 38,000 rodents captured in nearly 280,000 trap-nights of collecting effort covering a period of eight years from 1963-1971 were analyzed to indicate the relative frequency of capture of rodent species within and among several biotic communities. The relative fidelity of rodent species to given habitat types and the amount of competition by other rodent species within each community were also quantitated. Estimates were also made of the average absolute density of rodents within each of the major communities.

The frequency distributions of dried lens weights of five rodent species were analyzed and comparisons made with equivalent data from previous years. Such variables as the onset of breeding, peak periods of production, age structure of the population and population rates were compared within and among years and species.

PRODUCTION OF NATIVE MAMMALS

Breeding colonies of eight native rodent species were maintained during 1971 with a net production of 2,793 animals. Data pertaining to the vital statistics of each colony is presented.

SURVEY OF ZOONOTIC DISEASES

Specimens Collected for Disease Diagnosis

Vertebrates

During 1971, field sampling of the fauna for disease surveillance was conducted following the systematic schedule shown in Table 1 which results in approximately 3,250 rodents and 942 lagomorphs being collected and processed for diagnosis during the calendar year. In addition, approximately 100 other mammalian vertebrates are sampled annually. Figure 1 geographically locates the 25 areas encompassing about 5,500 square miles in west-central Utah from which these specimens were routinely collected.

Table 2 summarizes actual rodents collected during 1971 by species, collecting area and by area group. The majority of these rodents were captured alive in can-traps, with a line of 40 traps set 30 feet apart constituting one trapline. A total of 497 such lines were set for a total of more than 34,000 trap-nights and produced 3,623 rodents from which 3,186 of 22 species from 26 collecting areas were processed for disease diagnosis.

One species, Peromyscus maniculatus, comprised 54.4% of the total rodent sample. Other dominant species and the percentage contribution of each to the sample were as follows: Dipodomys ordii, 5.7%; Eutamias minimus, 5.5%; Ammospermophilus leucurus, 5.1%; and the pocket mice Perognathus formosus and Perognathus parvus, each 5.1%. The species composition of the sample is in accord with that determined in previous recent years but does reflect small increases or decreases in certain species which are known to be related to weather factors, general rodent population levels, and distribution of trapping effort among the various months.

Table 3 summarizes the mammals other than rodents which were processed during the current report period. Included are 1,130 specimens of 9 species from 27 collecting areas. The primary species collected were 987 Lepus californicus, 75 Sylvilagus audubonii, 21 Lynx rufus, 16 Odocoileus hemionus, and 13 Canis latrans. Of this group of animals, only the L. californicus are collected systematically using a shotgun or a 22 caliber rifle from the back of a truck either during the day or with spotlight at night. The other species were taken by hand, in steel or live traps, or by shooting, on a chance occurrence basis. Approximately 30% of the L. californicus were from southern Idaho and were provided by the U.S. Jack Rabbit Research Station, Twin Falls, Idaho, to give a picture of disease incidence in an area remote from our routine study area.

The U.S. Government furnished serum samples from 1,684 sheep and 225 cattle collected during 1971 for testing for evidence of disease. The herd units, collection areas and months of collection along with results of testing are shown in a table in the discussion of tularemia in this report.

Table 1. Collecting schedule for rodents and lagomorphs.

Group I Areas	Dec - Jan		Feb - Mar		Apr - May		Jun - Jul		Aug - Sep		Oct - Nov		Annual Sample Per Area	
	Rod.	Lago.	Rod.	Lago.	Rod.	Lago.	Rod.	Lago.	Rod.	Lago.	Rod.	Lago	Rod.	Lago.
Old Lincoln Highway	25	5	25	5	25	5	25	5	25	5	25	5	150	30
Wig Mountain	25	5	25	5	25	5	25	5	25	5	25	5	150	30
Camelback Mtn.	25	5	25	5	25	5	25	5	25	5	25	5	150	30
Dugway Valley	25	5	25	5	25	5	25	5	25	5	25	5	150	30
Granite Mtn.	25	5	25	5	25	5	25	5	25	5	25	5	150	30

Group II Areas	Dec - Feb		Mar - May		Jun - Aug		Sep - Nov		Annual Sample Per Area	
	Rod.	Lago.	Rod.	Lago.	Rod.	Lago.	Rod.	Lago.	Rod.	Lago.
South Cedar Mtns.	35	5	35	5	35	5	35	5	140	20
Government Creek	35	5	35	5	35	5	35	5	140	20
Iosepa	35	5	35	5	35	5	35	5	140	20
Condie	35	5	35	5	35	5	35	5	140	20
Big Davis Mtn.	35	5	35	5	35	5	35	5	140	20
West Cedar Mtns.	35	5	35	5	35	5	35	5	140	20

Group III Areas	December - March		April - July		August - November		Annual Sample Per Area	
	Rod.	Lago.	Rod.	Lago.	Rod.	Lago.	Rod.	Lago.
Erickson Pass	40	8	40	8	40	8	120	24
Dugway Mountains	40	8	40	8	40	8	120	24
Fish Springs	40	8	40	8	40	8	120	24
Gold Hill	40	8	40	8	40	8	120	24
Trout Creek	40	8	40	8	40	8	120	24
Callao	40	8	40	8	40	8	120	24

Group IV Areas	December - May		June - November		Annual Sample Per Area	
	Rodents	Lagomorphs	Rodents	Lagomorphs	Rodents	Lagomorphs
Lakeside	40	8	40	8	80	16
Stansbury	40	8	40	8	80	16
Benmore	40	8	40	8	80	16
Deep Creek Mtns.	40	8	40	8	80	16
East Wendover	40	8	40	8	80	16
South Wendover	40	8	40	8	80	16
West Wendover	40	8	40	8	80	16
North Wendover	40	8	40	8	80	16
Wasatch Front	50		50		100	
Special Studies					200	
Non-local Lagomorphs						400
				TOTALS:	3250	942

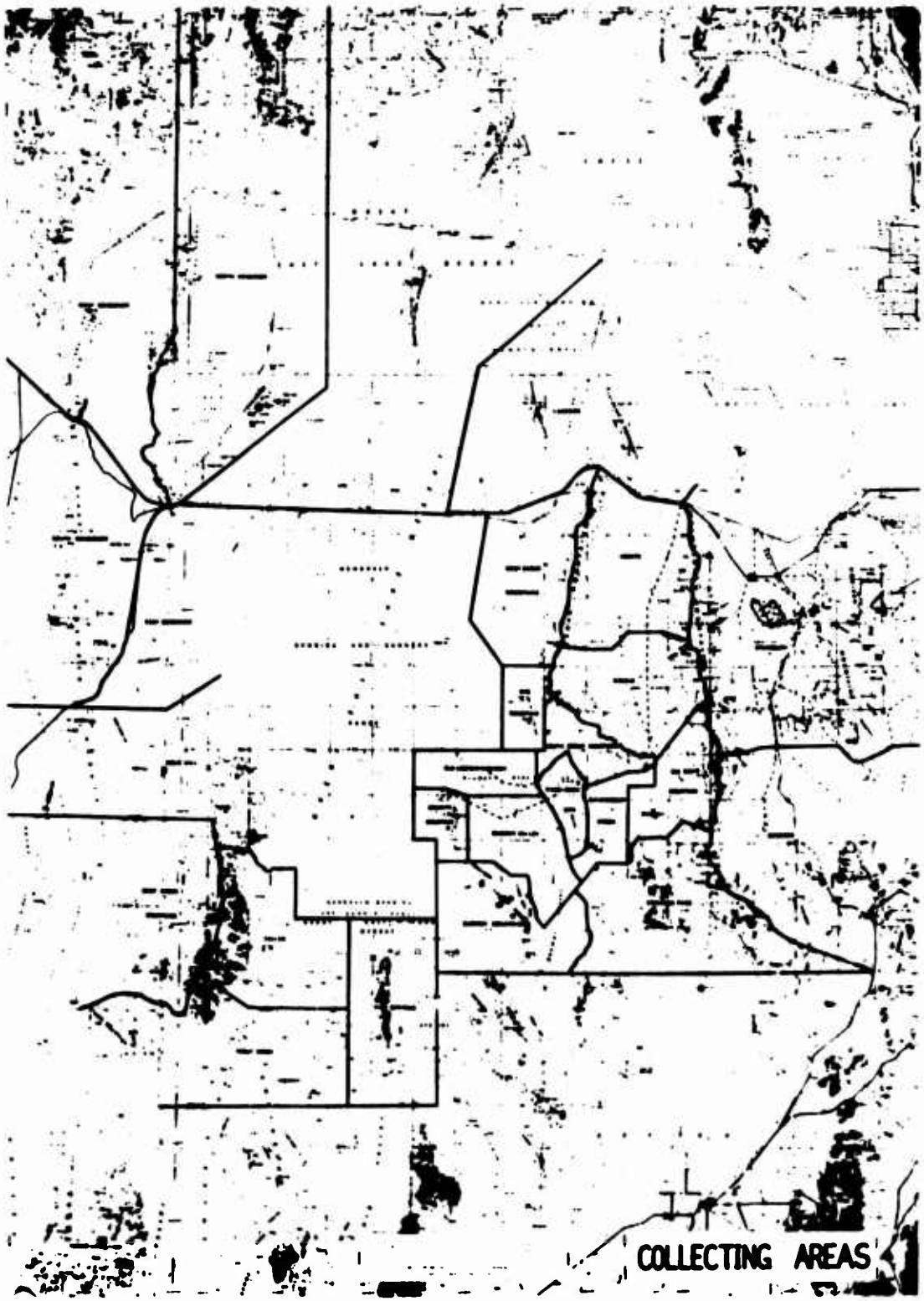


Figure 1. Map showing collection areas covering approximately 5,500 square miles from which rodents and lagomorphs are routinely collected.

Table 2. Rodents processed for disease diagnosis by areas of collection, 1971.

GROUPS AND COLLECTING AREAS																													
GROUP I																													
Old Lincoln Highway																													
Big Mountain																													
Camelback Mountain																													
Dugway Valley																													
Granite Mountain																													
GROUP II																													
South Cedar Mountains																													
Government Creek																													
Tooele																													
Dandie																													
Big Davis Mountain																													
West Cedar Mountains																													
GROUP III																													
Erickson Pass																													
Dugway Mountains																													
Fish Springs																													
Gold Hill																													
Trout Creek																													
Callao																													
GROUP IV																													
Lakeside																													
Stansbury																													
Benmore																													
Deep Creek Mountains																													
East Wendover																													
South Wendover																													
West Wendover																													
North Wendover																													
GROUP V																													
Bryce Canyon	60		83			32							51					3							209	209			
Total	176	26	83	162	1	32	22	163	161	183	23	88	160	1732	85	4	92	2	2	3	3	3	3184						
Percent of Total	5.5	0.8	2.6	5.1	0.0	1.0	0.7	5.1	5.1	5.7	0.7	2.7	4.6	54.6	2.7	0.1	2.9	0.06	0.06	0.09	0.09	0.09							

Table 3 Mammals other than rodents processed for disease diagnosis by area of collection, 1971.

GROUPS AND COLLECTING AREAS / SPECIES	ORDER LAGOMORPHA *Sylvilagus audubonii* Audubon cottontail	*Lepus californicus* Black-tailed jack rabbit	ORDER CARNIVORA *Canis latrans* Coyote	*Vulpes macrotis* Kit fox	*Taxidea taxus* Badger	*Spilogale putorius* Spotted skunk	*Lynx rufus* Bobcat	*Felis catus* Domestic cat	ORDER ARTIODACTYLA *Odocileus hemionus* Mule deer	Area Total	Group and Grand Total
GROUP I											
Old Lincoln Highway		30		1	1					32	
Wig Mountain		30								30	
Camelback Mountain	4	31	5	4	1		1			46	167
Dugway Valley		30		2						32	
Granite Mountain		27								27	
GROUP II											
South Cedar Mountains		20	1				5			26	
Government Creek	6	28	5		6	1	8			54	
Iosepa		20								20	296
Condie		20	2				7		9	38	
Big Davis Mountain	6	125							7	138	
West Cedar Mountains		20								20	
GROUP III											
Erickson Pass	1	24								25	
Dugway Mountains		24								24	
Fish Springs		22								22	
Gold Hill	16	24								40	161
Trout Creek		24								24	
Callao		24						2		26	
GROUP IV											
Lakeside		16								16	
Stansbury	1	42								43	
Bennore		16								16	
Deep Creek Mountains		16								16	
East Wendover		11								11	207
South Wendover		16								16	
West Wendover		16								16	
North Wendover		16								16	
Delta	41	16								57	
GROUP V											
Twin Falls		299								299	299
Total	75	987	13	7	8	1	21	2	16		1130

Table 4. Host relationship of ticks collected and examined during 1971. Ticks and hosts are listed in order of numbers collected. Only hosts with naturally occurring ticks are included in the host sample.

HOST	Number of Hosts Contributing Ticks	Number of Hosts Examined	Dermacentor parumapertus	Ixodes kingi	I. pacificus	Haemaphysalis leporis-palustris	I. sp.	I. woodi	Ornithodoros sparmus	Ixodes tellingi	Otobius lagophilus	Ixodes texanus	Dermacentor andersoni	Ixodes sculptus	Dermacentor sp.	Total
Lepus californicus	443	605	2657			150					20		7			2834
Peromyscus maniculatus	269	1732	88	1180	278		18		8						1	1573
Dipodomys ordii	129	183	430	609						2						1041
Perognathus parvus	33	163	139	77												216
Dipodomys microps	19	23	33	61												94
Neotoma lepida	15	92	3	15				32	15							65
Perognathus formosus	14	161	1	10			10			19						40
P. longimembris	10	22	86	4												90
Ammospermophilus leucurus	9	162	7	6										1		14
Peromyscus truei	8	85	4	1	9				3							17
P. crinitus	7	140		4			6		1							11
Sylvilagus audubonii	6	75	14			47										61
Reithrodontomys megalotis	2	88	3	2												5
Onychomys leucogaster	2	4		34												34
Vulpes macrotis	2	7										6				6
Spermophilus lateralis	1	32												5		5
Sylvilagus nuttallii	1					5										5
Spilogale putorius	1											6				6
Homo sapiens	1				1											1
Total	972	3574	3465	2003	288	202	34	32	27	21	20	12	7	6	1	6118

Invertebrates

The rodents and other mammalian specimens were examined for ticks and fleas as part of the disease survey porcessing procedure. Representative samples were collected, sorted into pools with regard to kind of ectoparasite, host species, collecting area and trapline, and were identified to species.

Ticks

The 6,118 ticks collected and identified were hosted by 13 species of rodents, 3 lagomorphs, 2 carnivores, and 1 human as shown in Table 4. Only 11 of the 22 species of ticks known to inhabit the study area were represented in the collection with 56.6% of the total specimens being Dermacentor parumapertus and 32.7% being Ixodes kingi. The relative abundance of the tick species and the host-parasite relationships noted were consistent with findings in previous years. A total of 5,852 ticks in 285 pools were injected into indicator animals to detect pathogens.

Tabanids

During July and August, a special effort was made to sample deerflies and horseflies along the south end of Great Salt Lake, Utah Lake, Iosepa, Delta, Stansbury and Fish Springs. The result of this effort, as shown in Table 5, was 1,422 individual tabanids which were sorted into 42 pools and inoculated into indicator animals to detect pathogens, primarily Francisella tularensis. Of the total number of individuals, 804 were Chrysops discalis, 596 were C. fulvaster, 10 were C. aestuans and 12 were Tabanus punctifer.

Fleas

The 3,019 fleas collected and identified during 1971 were recovered from 808 mammalian hosts. These hosts consisted of 14 rodents, two lagomorphs and one carnivore species (Table 6). Of the 28 species of fleas determined, Monopsyllus w. wagneri was most abundant constituting 39.5% of the total. Although that species occurred on three other host species, it was taken mainly from Peromyscus maniculatus. The other two most common species which occurred in the sample included Monopsyllus eumolpi, which constituted 11.3% of the sample and Thrassis bacchi gladiolis which constituted 9.5%. These two species were hosted by Eutamius spp. and Ammospermophilus leucurus respectively. Over half of the total hosts examined consisted of 474 P. maniculatus which hosted 59% of the total fleas. Twenty-one species of fleas infested P. maniculatus. Other host-parasite relationships and relative abundance may be determined by inspection of this same table. A total of 2,195 fleas collected and sorted into 185 pools, were injected into indicator animals for detection of pathogens.

A group of 860 fleas taken from 321 animals collected during 1970 were identified, sorted into 55 pools and injected into indicator

animals for the detection of pathogens. These fleas were held over and given priority after indications of epizootics were noted in their respective collection localities. The areas involved include canyons of the Deep Creek Mountain Range and nearby localities, and Zion and Bryce National Parks areas. This group of 13 species of fleas was taken from ten host species.

Table 5. Tabanids collected for disease surveillance, July and August, 1971.

Species	Pools	Individuals	Area
Chrysops discalis	23	804	
	6	187	Iosepa
	1	65	Fish Springs
	1	5	Stansbury
	6	300	Wasatch Front
	8	227	Delta
	1	20	Utah Lake
C. fulvaster	15	596	
	7	367	Iosepa
	3	60	Stansbury
	5	169	Utah Lake
C. aestuans	1	10	
	1	10	Iosepa
Tabanus punctifer	3	12	
	2	9	Iosepa
	1	3	Fish Springs
Totals	42	1422	

Table 6 Host relationships of fleas collected from disease surveillance specimens, 1971.

	Peromyscus maniculatus	Ammospermophilus leucurus	Dipodomys ordii	Eutamias umbrinus	Eutamias minimus	Peromyscus crinitus	Neotoma lepida	Reithrodontomys megalotis	Sylvilagus audubonii	Eutamias dorsalis	Peromyscus truei	Spermophilus lateralis	Lynx rufus	Perognathus parvus	Dipodomys microps	Lepus californicus	P. formosus	TOTALS
Host Number	474	45	61	51	67	24	15	2[illegible]	9	10	3	13	1	4	3	2	4	808
[illegible] W. wagneri	1185				4	2				4								1195
Meropsyllus sumolpi				173	162					7								342
Thrassis bacchi gladiolis	3	282														3		288
[illegible] sinomys	187					71		12									2	272
[illegible] perseri	13		165							1				4				183
[illegible] leucopus	75		1		1	1		36			16			2			2	134
Epiteira stanfordi	97							1										05
Malaraeus telchinum	83																	83
[illegible] sexdentatus	3					5	71											79
Stenistomera macrodactylla	20					57		2										79
[illegible] hisodasys K. keeni	41									12								53
Cediopsylla [illegible] inaequalis									31									31
Anomiopsyllus amphibolus	4					12	15											31
Peromyscopsylla h. adelpha	30																	30
Meringis dipodomys	19		5												6			30
Hoplopsyllus anomalus		14																14
Pulex irritans									1				13					14
T. b. caducus												14						14
Rhadinopsylla heiseri		11																11
Callistopsyllus terinus	6					3												9
Rhadinopsylla sectilis	5									1								6
Hystrichopsylla linsdalei	3															2		5
Thrassis arilis compestris			5															5
Stenistomera alpina	4					1												5
Rhadinopsylla micropsylla	3																	3
Atyphloceras m. multidentatus	2																	2
Megarthroglossus smiti	2																	2
Catallagia decipiens	1																	1
TOTALS	1786	307	176	173	167	152	86	51	32	25	16	14	13	6	6	5	4	3019

Results of Disease Ecology Investigations

Francisella tularensis (Tularemia)

Activity during 1971 directed toward tularemia ecology included the detection of 15 serological reactors using the tube agglutination test (among which were 13 cottontails) and the isolation of five times of the causative organism in the routine disease survey, the investigation of two human epidemics of tularemia, conduct of experimental infections in cottontails and the development of the much more sensitive hemagglutination test which revealed a much greater incidence and geographic spread of tularemia activity than previously known. Each of these aspects will be discussed in detail.

Results of Disease Surveillance

Serologic evidence of F. tularensis was found in 13 S. audubonii collected at Delta and in two badgers collected in Dugway Valley and Government Creek (Table 7). Isolations of the organism were made from the pooled tissues of two jack rabbits from Stansbury in June, from the pooled tissues of four cottontails taken in August in the Delta area, from a pool of 23 H. leporis-palustris ticks removed from jack rabbits from the Stansbury area in April, from a pool of 43 C. discalis collected in July in the Iosepa area, and from another pool of 105 of these deerflies collected during August near Delta (Table 8).

Comparisons of incidence rates of tularemia activity in wildlife specimens in the animal species found positive from 1967 through 1971 and by animal groupings and by areas may be made by reference to Tables 9 and 10.

Virulence studies of the five strains isolated from wildlife sources as well as one isolated from a human case are shown in Table 11.

The results of testing 1,684 sheep serum samples and 225 cattle serum samples collected and supplied in 1971 by the U.S. Government are shown in Tables 12 and 13 by month of collection, herd unit and collection area. Overall, 2.23% of the cattle gave positive agglutination reactions. The reactor rate among cattle is not significantly different from that found during the previous four years with incidence varying during this time span from 0.4% in 1970 to 3.8% in 1969. These rates are, however, a drastic reduction from the 22% incidence during 1965 and 1966, the 48% of 1964 and the 55% of 1960 and 1962. Only in herd unit #30, which grazes in the Benmore-Vernon area, was there any significant incidence of reactors with 4 of the 5 positives being detected here.

The incidence of agglutinating antibodies against F. tularensis among sheep samples, at 4.33% overall, was not significantly different than the 3.9% incidence found during 1970. No sheep samples were collected during 1968 or 1969 but adequate numbers (ranging from 458 to 1,579) were tested during the 1963-67 period. During these years,

Table 7. Evidence of Francisella tularensis in wildlife specimens during 1971 as determined by specific agglutinating antibodies using an antigen prepared from a locally isolated strain.

Species	Host Number	Area	Reciprocal of Titer
LAGOMORPHS			
Sylvilagus audubonii	71G 227,228	Delta	40,160
S. audubonii	71H 100,101, 103,220	Delta	320,80, 160,160
S. audubonii	71L 103,104,111, 122,126,127, 128	Delta	320,640,80 40,160,80, 40
OTHER VERTEBRATES			
Taxidea taxus	71B 381	Dugway Valley	320
Taxidea taxus	71L 113	Government Creek	20

Table 8. Isolation of Francisella tularensis from wildlife tissue and invertebrate specimens collected in 1971.

Host animal species	Number animals in pool	Invertebrate species	Number Invertebrate	Host Number	Collecting area
		TISSUE ISOLATIONS			
Lepus californicus	2	-	-	71F 89, 90	Stansbury
Sylvilagus audubonii	4	-	-	71H 100-103	Delta
		INVERTEBRATE ISOLATIONS			
L. californicus	3	Haemaphysalis leporis-palustris (ticks)	23	71D 70-72	Stansbury
-	-	Chrysops discalis (flies)	43	71G 279	Iosepa
-	-	C. discalis (flies)	105	71G 233, 234	Delta

Table 9. Incidence of Francisella tularensis in wildlife specimens of the Great Basin region as determined by specific agglutinating antibodies and isolations of the organism, 1967-1971 inclusive.

Species	1967 Positive/Total Isolation	%	1968 Positive/Total Isolation	%	1969 Positive/Total Isolation	%	1970 Positive/Total Isolation	%	1971 Positive/Total Isolation	%
RODENTS										
Ammospermophilus leucurus	1/430	0.2	0/157	-	0/99	-	0/218	-	0/162	-
	(1)	0.2								
Spermophilus townsendii	0/8	-	1/27	3.7	0/72	-	0/30	-	0/1	-
			(1)	3.7						
Peromyscus crinitus	0/55	-	0/86	-	0/122	-	0/128	-	0/140	-
	1*	1.8								
Mus musculus	0/17	-	0/2	-	0/1	-	0/4	-	0/3	-
	(2)	11.5								
Others	0/2444 (25 Species)	-	0/2832 (24 Species)	-	0/3208 (22 Species)	-	0/3026 (22 Species)	-	0/2880 (18 Species)	-
Total	1/2954	0.03	0/3104	-	0/3502	-	0/3406	-	0/3186	-
	(3) 1*	0.13	(1)	0.03						
LAGOMORPHS										
Lepus californicus	0/837	-	0/1294	-	0/1722	-	0/991	-	0/984	-
	1*	0.1			1*	0.06			(1) 1*	0.2
Sylvilagus audubonii	0/23	-	0/31	-	0/63	-	0/17	-	13/75	17.3
									(1)	1.3
Others	0/6 (3 Species)	-	0/15 (3 Species)	-	0/29 (2 Species)	-	-	-	-	-
Total	0/866	-	0/1340	-	0/1814	-	0/1008	-	13/1059	1.22
	1*	0.11			1*	0.06			(2) 1*	0.28
OTHER VERTEBRATES										
Canis latrans	0/2	-	0/1	-	0/9	-	3/15	20.0	0/13	-
Vulpes macrotis	5/40	12.5	1/31	3.2	1/21	4.8	1/29	3.4	0/11	-
Taxidea taxus	2/2	100.0	1/2	50.0	1/9	11.1	6/16	37.5	2/8	25.0
Odocoileus hemionus	1/25	4.0	0/48	-	2/52	3.8	0/22	-	0/16	-
Others	0/10 (4 Species)	-	0/3 (2 Species)	-	0/8 (4 Species)	-	0/8 (4 Species)	-	0/20 (3 Species)	-
Total	8/79	10.12	2/85	2.4	4/99	4.04	10/90	11.11	2/68	2.94
AVES										
Eremophila alpestris	1/156	0.6	0/126	-	0/182	-	-	-	-	-
			1	0.8						
Others	0/460 (25 Species)	-	0/418 (27 Species)	-	0/262 (30 Species)	-	0/19 (4 Species)	-	0/3 (3 Species)	-
Total	1/616	0.16	0/544	-	0/444	-	0/19	-	0/3	-
			1	0.18						

* Indicates isolation of organism from ectoparasite

_ Indicates conversion titer in indicator animal (guinea pig)

() Indicates isolation of organism from tissues

Table 10. Incidence of *Francisella tularensis* in wildlife specimens of the Great Basin region as determined by specific agglutinating antibodies and isolation of the organism, 1967-1971 inclusive.

Year	Number Positive	Number Tested	Percent Positive	Areas yielding positive specimens
				RODENTS
1967	1	2954	0.03	South Cedar Mountain
	(3) 1*		0.13	Government Creek, Callao, Wasatch Front
1968	0	3104	-	----
	(1)		0.03	Camelback Mountain
1969	0	3502	-	----
1970	0	3406	-	----
1971	0	3186	-	----
				LAGOMORPHS
1967	0	866	-	----
	1*		0.11	Erickson Pass
1968	0	1340	-	----
1969	0	1814	-	----
	1*		0.06	Iosepa
1970	0	1008	-	----
1971	13	1059	1.22	Delta
	(2) 1*		0.28	Stansbury, Delta, Iosepa
				OTHER VERTEBRATES
1967	3	79	10.12	Camelback Mountain, Old River Bed, Callao, Government Creek, Duchense-Roosevelt
1968	2	85	2.40	Camelback Mountain, Duchense-Roosevelt
1969	4	99	4.04	Camelback Mountain, Condie, Stansbury
1970	10	90	11.11	Wig Mountain, Camelback Mountain, Dugway Valley, South Cedar Mountain, Condie
1971	2	68	2.94	Dugway Valley, Government Creek
				AVES
1967	1	616	0.16	Old Lincoln Highway
1968	0	544	-	----
	1		0.18	Camelback Mountain
1969	0	444	-	----
1970	0	19	-	----
1971	0	3	-	----

1 Indicates number of serological positive wildlife sera

1* Indicates isolation of the organism from ectoparasite

1 Indicates indicator animal (guinea pig) conversion titers

(1) Indicates isolation of the organism from tissues

Table 11. Virulence studies of *Francisella tularensis* isolated during 1971. Number of organisms injected determined by plate counts.

Isolate Number and source	Experimental animal	Number of organisms injected	Survivors/ number infected	LD_{50}
71D 70 (*D. parumapertus* ticks ex *L. californicus*, Stansbury)	White mouse	20	0/10	<20
	Guinea pig	20	0/5	<20
		1×10^3	0/5	
		1×10^5	0/6	
	White rat	20	1/6	<20
		1×10^3	1/6	
		1×10^5	0/6	
71F 89 (*L. californicus* tissues, Stansbury	White mouse	144	0/10	<144
	Guinea pig	144	0/6	<144
	White rat	144	0/5	<144
71G 233 (*C. discalis*, Delta)	White mouse	6	0/5	<6
	Guinea pig	6	0/3	<6
		1.08×10^3	0/4	
	White rat	6	3/5	>6,<1080
		1.08×10^3	2/5	
		1.08×10^5	0/4	
	White rabbit	191	0/2	<191
71G 279 (*C. discalis*, Iosepa)	White mouse	16	0/10	<16
	Guinea pig	16	0/5	<16
		8×10^3	0/6	
	White rat	16	2/4	16
		8×10^3	1/5	
		8×10^5	2/5	
	White rabbit	69	0/2	<69
71H 100 (*S. audubonii* tissues, Delta)	White mouse	20	0/10	<20
	Guinea pig	20	0/4	<20
	White rat	20	2/5	<20
		2.17×10^3	1/5	
		2.17×10^5	0/5	
	White rabbit	23	0/2	<23
"Cole" (Strain isolated from blood of human case, Delta)	White mouse	5	0/5	< 5
	Guinea pig	5	0/1	< 5
		8.2×10^2	0/4	
	White rat	5	3/5	>5,<820
		8.2×10^2	2/5	
		8.2×10^4	0/4	

Table ... Incidence of *Francisella tularensis* in domestic livestock during 1971 as determined by specific agglutinating antibodies in relation to grazing area and season of the year.

Herd Unit Number	Grazing Area Summer	Grazing Area Winter	Collection Month	Sample Size	Number Positive	Percent Positive	Collection Month	Sample Size	Number Positive	Percent Positive
Sheep										
1	Uinta Mt.	Duguey Mt	April	33	2	6.1	November	27	0	----
2	Uinta Mt.	Big Davis Mt	April	33	4	12.1	November	31	5	16.1
3	Uinta Mt.	Keg Mt.	April	33	1	3.0	November	31	1	3.2
4	Uinta Mt	S. White Rock	April	32	4	12.5	November	31	0	----
5	Uinta Mt	N. White Rock	April	33	5	15.2	December	31	0	----
6	Strawberry	Topaz Mt.	April	33	1	3.0	November	31	1	3.2
7	Monte Cristo	N.E. Skull Valley	April	33	8	24.2	December	31	3	9.7
8	Monte Cristo	E. Cedar Mt	April	33	3	9.1	December	31	0	----
9	Monte Cristo	W. Cedar Mt	April	33	0	----	December	31	0	----
10	Monte Cristo	W. Cedar Mt	April	33	1	3.0	December	31	0	----
11	Monte Cristo	Pilot Mt	May	33	0	----	December	31	0	----
12	Monte Cristo	E. Toana Mt.	May	33	3	9.1	December	31	0	----
13	Smith-Morehouse	N. Grassy Mt.	April	33	0	----	November	31	3	9.7
14	Park City	Utah Peak	April	33	0	----	November	31	3	9.7
15	East Canyon	S. Lakeside Mt	April	33	0	----	November	30	1	3.2
16	East Canyon	Dalle	May	33	1	3.0				
17	Monte Cristo	W. Cedar Mt.	April	33	0	----	December	31	0	----
18	Monte Cristo	W. Cedar Mt	April	33	0	----	December	31	0	----
19	Monte Cristo	Toana Mt	-----				December	31	2	6.4
20	Seegotsme	Topaz Mt	April	33	0	----	November	31	0	----
21	Weber Mt	Conger Mt.	May	33	1	3.0	October	32	2	6.2
22	East Canyon	S.W. Lakeside Mt.	May	33	2	6.1	November	31	4	12.9
23	Chalk Creek	W. Gold Hill	May	33	3	9.1	November	31	2	6.4
24	Lost Creek	West Desert	May	33	0	----	November	32	0	----
25	Chalk Creek	N. Callao	May	33	0	----	November	31	6	19.3
26	Chalk Creek	N. Deep Creek	May	33	0	----	November	31	0	----
27	S.W. Duguey Mt.	Squirrh Mt.	May	33	0	----	December	20	0	----
28	E. Deep Creek	Callao Meadows	January	6	0	----				
33	E. Oakley	W. Duguey Mt.					December	31	1	3.2
	Total			861	39	4.5		823	34	4.1
Cattle										
28	E. Deep Creek	Callao Meadows	January	2	0	----				
28	E. Deep Creek	Callao Meadows	June	29	1	3.4	November	31	0	----
29	Grouse Creek Mt.	S. Lucin	June	35	0	----	November	31	0	----
30	Bonnore	Vernon	June	29	2	6.9	December	23	2	8.7
31	White Rock	Orr's Ranch	July	32	0	----	December	13	0	----
	Total			127	3	2.4		98	2	2.0

Table 13. Incidence of *Francisella tularensis* agglutinating antibodies in domestic livestock sera collected in the Great Salt Lake Desert region, 1967-1971.

Year	Positive 1:40 or *	Number Tested	Percent Positive	Areas yielding positive specimens
				CATTLE
1967	14	684	2.0	Ibapah, Clover, Cedar Fort
1968	1	73	1.4	Grouse Creek
1969	20	521	3.8	Clover, Callao
1970	2	483	0.4	Clover, Vernon
1971	5	205	2.4	Callao, Vernon
				SHEEP
1967	172	971	17.7	Dugway Mountain, Gold Hill, Iosepa, North Skull Valley, Topaz, Cedar Valley, Lakeside, Cedar Fort, Oquirrh Mountains, Utah Lake
1970	46	1205	3.9	Dugway Mountain, Davis Mountain, Skull Valley, East Cedar Mountain, North Dugway Ranch, Pilot Peak, West Desert Wells, North Skull Valley
1971	75	1684	4.5	Dugway Mountain, Big Davis Mountain, Keg Mountain, Topaz, South White Rocks, North White Rocks, North East Skull Valley, East Cedar Mountain, West Cedar Mountain, East Topaz, Conger Mountain, Gold Hill, Lakeside, Chalk Creek, East Canyon, Holiday Park, Park City, Davis Mountain, West Dugway Mountain
				HORSES
1967	13	18	72.2	Callao, Vernon
				SWINE
1967	0	8	-	----
				GOATS
1971	1	6	16.7	Grantsville

* Sheep were considered positive at 1:40 or greater

the rates of seropositives were, respectively, 14%, 30%, 42%, 16% and 18%, all significantly higher than the 1970 and 1971 rates.

Approximately half of the sheep samples were collected in April and May and the other half from the same herd units was collected in November and December. The spring incidence of 4.5% was virtually identical to the 4.1% late fall incidence. Individual herd unit incidence ranged from 0.0% to 24.2% in the spring and from 0.0% to 19.3% in the fall. Four herd units (#2,4,5, and 7) showed significantly higher incidence rates than the average during the spring sampling; the titers were all quite low (79.5% at 1:20, 15.4% at 1:40 and 5.1% at 1:80) indicating that infection had probably not taken place during the spring of 1971 and making it impossible to define the areas where infection was acquired. Only three herd units (#2, 22, and 25) had reactor rates significantly higher than the average during the fall collection; the animals in these herds spent the summer in diverse localities (Uinta Mountains, East Canyon and Chalk Creek). Only one herd unit (#25) which winters at North Callao and summers in Chalk Creek showed a significant increase from 0.0% to 19.3% in seropositives from the spring to the fall sampling period although 6 others also increased slightly;the incidence in 8 units decreased during this period and in 10 others it remained unchanged.

Grantsville Epidemic

Reported human cases of tularemia in Utah have followed the same declining trends as noted nationally over the last 30 years. The maximum number of cases reported in any one year, 73, occurred in 1938. The annual number of cases reported averaged 37 during the 1940's, 25 during the 1950's, and 12 during the 1960's. There is evidence, however, that the decline in the number of reported cases, both nationally and in Utah, is in part an artifact caused by failure to detect, confirm and report cases. Utah does have one of the highest case rates in the nation: during the 1960-69 decade Utah's case rate was 1.18 per 100,000 population, being exceeded only by Arkansas with 2.78 and Wyoming with 2.73.

During 1971, 39 cases were identified in the state, this number being greater than had been reported since 1953 and prior to that since 1948. Most cases of tularemia in Utah have been isolated events and scattered geographically. However, in 1971, two epidemics occurred involving 7 persons in the Grantsville area and at least 16 in the Delta area. Both of these outbreaks were investigated in a joint effort by EcoDynamics, Inc. and the Utah State Division of Health. Dr. Larry Klock of the latter group gave us the utmost in co-operation and his aid is gratefully acknowledged.

All suspect cases of tularemia in both the Grantsville and Delta outbreaks were interviewed to obtain epidemiological information and an attempt was made to obtain acute and convalescent blood specimens. A diagnosis of tularemia was made only if any of the following criteria were met: (1) A four-fold or greater rise in tularemia agglutinating antibodies; (2) A tularemia antibody titer of 1:160 or greater accompanied by an epidemiological and clinical history compatible with acute

tularemia, or (3) Culture of F. tularensis directly from a patient. All human serology was conducted by the Utah State Division of Health Laboratories whereas all wildlife diagnostic work was conducted by EcoDynamics, Inc. laboratories.

Grantsville, a town of 3,000 persons, is located in Tooele County, in the northern portion of the Stansbury collecting area, approximately 35 miles west of Salt Lake City. It is an irrigation farming and ranching community located at 4,420 feet elevation. The topography is flat to gently rolling and the farmland is interspersed and surrounded by desert shrubland. Although the last reported case of tularemia in Tooele County occurred in 1962, a number of isolates of F. tularensis have been made from mammals and arthropods in this county over the years.

Due to delay in recognizing and reporting the Grantsville cases, epidemiological and epizootiological studies were not commenced until July 8, one day after the first case was reported to the State Division of Health. It was later determined that the dates of onset of the 7 cases ranged from June 10 to June 28.

The disease occurred among 4 young children, ages 4 to 11 years, and 3 housewives. Most did not exhibit classic clinical symptoms and most were relatively mild. Six of the seven had an ulcerative lesion in the hair or on the neck accompanied by regional adenopathy; this is in contrast to the usual finding of a lesion on the extremities, trunk or cheek. No suggestive history of exposure to wild animals, ticks, deer flies or water could be elicited. One common denominator was found, however: all had been bitten by mosquitoes or biting gnats (Ceratopodonidae) either at their homes or in one localized area southwest of town.

Evidence of tularemia activity in the Grantsville area had been obtained earlier in the year as part of our routine disease surveillance activities. On April 5, 1971, 8 jack rabbits were collected 9 miles south of Grantsville. Although no indication of tularemia was found in the tissues or serum of these animals, a fully virulent strain of F. tularensis (71D70) was isolated from a pool of 23 H. leporis-palustris ticks parasitizing three of these rabbits. Again, as part of routine disease surveillance and prior to knowledge of human involvement, on June 15, 5 days after the first date of onset of a Grantsville case, another fully virulent isolate of F. tularensis (71F89) was made from the tissues of a pool of two jack rabbits of 8 collected at this same site.

Field investigations to identify the wild animal sources involved in the epidemic were commenced on July 10, approximately 2 weeks after the last date of onset. Between July 10 and July 20 the following specimens were collected near probable exposure sites and tested: 75 rodents of 5 species, 26 jack rabbits, 1 cottontail, 267 ticks from jack rabbits (207 D. parumapertus and 60 H. leporis-palustris), 15 ticks (D. parumapertus) from rodents, 79 fleas from rodents, 65 deer flies (60 Chrysops fulvaster and 5 C. discalis), 1,507 mosquitoes (including 764 Aedes dorsalis and 718 Culex tarsalis), 964 biting

gnats (Culicoides sp., probably variipennis and Leptoconops sp., probably kerteszi), 550 snipe flies (Symphoromyia sp.), and serum samples only from 6 goats, 4 domestic rabbits and 2 house cats. No evidence of F. tularensis activity was detected in any of these samples with the exception of an agglutinating antibody titer of 1:320 in a goat sampled near the location of the earlier isolates.

Another fully virulent isolate of F. tularensis (71G279) was made in connection with routine disease surveillance from a pool of 43 C. discalis collected July 26 at Timpie Springs in the Iosepa collecting area, 15 miles northwest of Grantsville. Two pools (125 individuals) of C. fulvaster, one pool (10 individuals) of C. aestuans and two pools (190 individuals) of Aedes dorsalis collected at the same time at this site were negative.

The failure to elicit a common history of exposure to one of the more common sources of tularemia, e.g., deer flies, ticks, wild animals or water, among the cases led to investigations of the only common denominator: bites by mosquitoes and biting gnats. Neither of these insects is ordinarily considered in tularemia epidemiology in the U.S. Mosquito-transmitted tularemia is very common in Scandinavia and the USSR, but has never been proved in the U.S. Francisella tularensis has been positively associated with mosquitoes only once in the U.S. when, during a tick-borne epidemic on a South Dakota Indian reservation in 1964, Aedes trivittatus mosquitoes killed guinea pigs following their injection and the guinea pigs gave a positive Ascoli test. Biting gnats of the genus Culicoides and Leptoconops have never been associated in any way with tularemia in the U.S. but they have been in the USSR.

Residents of Grantsville are familiar with and can differentiate among deer flies, mosquitoes and biting gnats. They complained of higher than average populations and annoyance by mosquitoes and gnats during 1971 noting that gnats were no longer causing difficulties at the time of our mid-July investigations but had been very troublesome during May and June. This corresponds with our findings during this study and with work in the general area from previous years. They also noted that deer flies were common in the area around Grantsville but few had been encountered as yet in 1971 and that it was normally late July or August before they became abundant. This also corresponds with our observations.

If mosquitoes were involved in the Grantsville outbreak, A. dorsalis was the species most likely to have been responsible. Although at the time of the July 20 sampling this species was not common in the town and at the potential exposure sites, being abundant only at one site two miles north of town which was not incriminated as a potential exposure area, dorsalis is the species which regularly has its early peak of population during May and early June in this area, corresponding with the time of exposure of the human cases. The populations of dorsalis then wane during mid-summer and are replaced by Culex tarsalis. Although C. tarsalis is primarily a bird-feeder, A. dorsalis readily takes blood meals from jack rabbits. Whatever the arthropod vector, it seems requisite that it obtain an infectious blood meal from jack

rabbits, the primary amplifier vertebrate for F. tularensis in the area. It should be noted that D. parumapertus, the tick responsible for maintenance of the organism and rabbit to rabbit transmission, rarely if ever attacks man. One factor that points away from a mosquito as a vector in the Grantsville outbreak is the fact that these vectors bite opportunistically on any exposed part of the body and do not preferentially seek the head and hair regions; this is inconsistent with the predominant location of the lesions in the cases.

There is rather strong circumstantial evidence incriminating the biting gnat as the vector in the Grantsville epidemic. Although peak populations of these gnats had long since passed and were no longer an annoyance in the town, on July 20 nearly 1,000 were captured in 3 carbon dioxide-baited light traps during a 24 hour period in fields 2-3 miles south of Grantsville. In addition, we know from observations extending over many years that these gnats readily feed upon jack rabbits as well as man. Finally, they do exhibit a definite preference for biting in the hair on the head.

Evidence that tularemia activity was extensive in the Grantsville area and other portions of the Stansbury collecting area was gained during and subsequent to the July and August investigations. Various objective and subjective measurements of jack rabbit abundance all indicated that the jack rabbit population was severely decimated in this area. Although jack rabbit populations are at record high levels in surrounding areas, these animals were virtually absent by the fall of 1971 and have remained so through April of 1972 in the Grantsville area.

Delta Epidemic

A total of 16 cases of tularemia were verified in the Delta area during 1971. Since 1962, only one other case, in 1967, had been reported. In contrast to the Grantsville outbreak, the Delta cases occurred in an area approximately 20 miles by 7 miles within a 10 mile radius west of Delta and included residents of the communities of Sugarville, Abraham, Sutherland, Deseret, and Oasis. This area, located 105 miles southwest of Salt Lake City in Millard County at approximately 4,600 feet elevation, is flat irrigation farming and ranchland country interspersed and surrounded by desert shrubland and interlaced with irrigation canals. This location has a place in the history of tularemia since it was here in 1919 that Francis, while investigating a disease of unknown etiology, recognized "deer fly fever", isolated the pathogen from jack rabbits, and named the disease tularemia. He noted that probably two dozen cases occurred in Millard County in each of the years 1917, 1918, 1919 and 1920, and that the disability of 2-3 months which accompanied the disease was of serious concern since it overtook farmers in the busy summer season.

The Delta cases had dates of onset ranging from July 12 to September 2 with 8 commencing in July, 7 in August and one in September. In contrast to the Grantsville epidemic, the clinical picture and transmission means were classic: affected persons had typical symtomology with cutaneous lesions on the extremities or cheek accompanied

by regional adenopathy and nearly all could recall being bitten by a deer fly a few days prior to onset of symptoms.

Again in contrast to the Grantsville outbreak, field collections of mammals and insects were made during the height of the epidemic on five separate days from July 22 to August 19. During this period, 14 jack rabbits, 9 cottontails, 227 C. discalis, 37 D. parumapertus from jack rabbits and 27 H. leporis-palustris from cottontails were collected and tested. Another 30 cottontails were live-trapped and their serum samples tested during late November.

At one site where a victim was able to define the precise locality where he had been bitten by a deer fly 8 days prior, 105 C. discalis were collected and pooled on July 22; F. tularensis of maximal virulence (71G233) was isolated from this pool. Although the relationship between deer flies and cases of human tularemia has been long known, and 13 isolations of the organism from deer flies (C. discalis, C. fulvaster and C. aestuans) have been made in Utah between 1964 and 1969, this marks the first time that infected deer flies have been found in nature in close geographic and time correlation with a human case.

At another Delta site located 15 miles south of the above-noted location, the pooled tissues of 4 cottontails collected August 10 yielded a fully virulent isolate of F. tularensis (71H100). This area was where three cases had received their infective deer fly bite; an isolate made from one of these cases ("Cole" isolate) also proved fully virulent. All of the 39 cottontails collected in the Delta investigation came from an area of less than one square mile at this site. Significant levels of agglutinating antibodies were detected in 13 (33.3%) of these lagomorphs.

The finding of these seropositive cottontails is extremely unusual and prompted laboratory studies to help clarify the results. These will be discussed in the next section of this report.

Although local residents complained of high deer fly populations, collections at the exposure sites and other areas where residents had pinpointed large numbers of these insects failed to confirm this. The average collection success using insect nets was only 6 flies captured per manhour of effort; in other Utah areas we have often encountered populations which yielded 100-200 deer flies per manhour. Based on the number of human cases and the relative abundance of deer flies, one must conclude that although fly populations were low the infection rate among the flies was quite high.

Jack rabbit populations were also very low during our field investigations from late July to mid-August although local residents stated that high populations were present up until the end of June, a time period which would coincide with the build-up of deer fly populations in this area. No evidence of a mass die-off of jack rabbits in the form of carcasses was detected in spite of an intensive effort; however, in the hot summer weather, decomposition of the carcasses would have taken place very rapidly and could easily have

gone undetected. Cottontail populations were spotty with some areas sustaining relatively large numbers and other areas none. Objective evaluations of cottontail populations are much more difficult to make, due to their size, burrowing proclivities and activity times, than are estimates of jack rabbit populations.

The basic transmission cycle of F. tularensis in the Delta area apparently involves a reservoiring and vectoring function of both D. parumapertus and H. leporis-palustris to and among jack rabbits and cottontails since both ticks infest both lagomorphs. The deer fly enters this basic epizootic cycle by feeding upon infective jack rabbits and then carries the infection either to other jack rabbits or to man by its bite. Cottontails probably are a minor source of infection for deer flies since these rabbits are primarily nocturnal in their activity and occupy underground burrows during the day when deer flies are active. Jack rabbits spend all their time above ground and would therefore be subject to deer fly attack even when inactive.

Tularemia in Cottontails

The unusual finding of the large number of cottontail seropositives prompted extensive laboratory studies employing these animals and strains isolated from the Delta area in an effort to explain the apparent contradiction that exposure to this organism is uniformly fatal for cottontails. It was hypothesized that: (1) Delta cottontails were more resistant to F. tularensis as a result of selection resulting from long association with the organism, or (2) the antibody detected was the result of a non-specific reaction and as such was not protective, or (3) an avirulent strain of F. tularensis present in the area was responsible for the antibody titers seen. Tests were conducted to refute or verify these hypotheses.

It was noted earlier that at the site where all additional seropositive cottontails were to subsequently come from, an isolate of F. tularensis (71H100) was made from the pooled tissues of four cottontails collected August 10. Unfortunately, the tissues had been pooled in the field and it was not possible to go back to individual animals to determine which one harbored the organism. Three of the animals in this pool exhibited significant titers of 1:320, 1:160 and 1:80 in the tube agglutination test. (These same animals also had hemagglutination titers of 1:4096, 1:256 and 1:256 as conducted by the Center for Disease Control, Ft. Collins, Colorado). Virulence studies conducted with standard laboratory animals (Table 14) indicated that this isolate was of full virulence with an LD_{50} of less than 20 organisms for white mice, guinea pigs, white rats and laboratory rabbits.

To test the first hypothesis stated above, experimental infections were conducted with cottontails live-trapped from the Delta site and with cottontails live-trapped at Gold Hill. The latter location is 95 miles northwest of Delta and does not have the recurrent history of tularemia activity as does Delta. None of the Gold Hill cottontails had detectable pre-inoculation levels of antibody against F. tularensis. Of the 13 Gold Hill animals receiving a

Table 14. Virulence studies of Francisella tularensis 71H100 isolated from a pool of cottontail (Sylvilagus audubonii) tissue.

Experimental Animal	Total No. Organisms Inoculated	Survivors/ No. Infected	LD_{50}	Average Day of Death
White Mice	20	0/10	<20	4
Guinea Pigs	20	0/4	<20	5
White Rats	20	2/5	<20	6
	2.17×10^3	1/5		5
	2.17×10^5	0/5		3
White Rabbits	23	0/2	<23	5
S. audubonii (Gold Hill)	10	0/13	<1.4	4-5
	1.4	0/2		6
S. audubonii (Delta)	1.4	1/7	<1.4	6

subcutaneous injection of 10 viable organisms of strain 71H100, all died on day 4 and 5 following injection, and F. tularensis was isolated from the spleen of each. This was expected and proved the virulence of the strain for normal cottontails.

Delta cottontails were then inoculated subcutaneously with a dosage of 1.4 organisms of the same strain. Of the 13 animals injected, 10 did not have detectable pre-inoculation antibody titers while 3 did have tube agglutination titers of 1:80, 1:320 and 1:640. (Two of these three also had hemagglutination titers of 1:1536 and 1:1024; there was insufficient serum from the third to perform this test). Of the 10 without pre-inoculation titers, 3 did not show titers at 30 days and can be assumed not to have received an injection of viable organisms. Of the remaining 7 of this group, only one survived, this animal converting to post-inoculation antibody titers of 1:160 in the tube agglutination and 1:512 in the hemagglutination test. Two of the three animals which had pre-inoculation titers also survived; the third, however, died, but did not show characteristic pathology nor was it possible to isolate F. tularensis from its tissues and therefore has been classified as a non-specific death.

These results showed that Delta cottontails do not possess any innate resistance to a virulent strain of F. tularensis isolated from the same area and are lethally susceptible to less than two organisms.

The results also suggested that the antibody detected was specific and protective. Additional work was done to confirm this by injecting three Delta cottontails which had agglutination titers of 1:80, 1:80 and 1:160 with 23 organisms of the same strain (71H100) used in the previous experimental infections. This time 23 organisms, a dosage lethal for white rabbits and all other laboratory animals, was injected with the result that all three animals survived. An attempt was made to detect a bacteremia in these animals by taking 1 ml of blood on days 5, 6 and 7 post-inoculation and injecting 0.5 ml into each of two mice. None of the mice died. This experiment confirmed the fact that the cottontail antibody detected is indeed protective.

The specificity of the cottontail antibody was tested by employing the micro-Ouchterlony diffusion technique, using as antigen polysaccharide (0.5 mg/ml) prepared according to the method of Nicholes and tested against anti-tularensis white rabbit serum and the sera from three Delta cottontails each with tube agglutinating and hemagglutinating antibody titers. The results showed that the antibody present was specific and would precipitate the F. tularensis polysaccharide antigen.

The finding of seropositive cottontails is extremely unusual, since, like jack rabbits and Utah rodents, these lagomorphs are highly susceptible to F. tularensis with exposure to 1-10 organisms of a virulent strain being fatal. The literature records only two other seropositive Sylvilagus, one in Washington and one in Georgia. In previous survey results obtained in the Dugway disease surveillance program, only one other cottontail out of approximately 350 tested was seropositive. This animal, collected at Grouse Creek in May 1963 (63E766), had a tube agglutination titer of 1:320. The tissues of this animal induced specific antibodies upon injection into guinea pigs. Several attempts to produce an infection in guinea pigs and mice from the stored tissues were not successful. The organism was finally isolated from modified casein partial hydrolysate broth inoculated with tissues of mice after two blind three-day passages. This strain was of extremely low virulence with the LD_{50} (intraperitoneal injection) for mice being 10^5, for guinea pigs 10^8, and for white rats and laboratory rabbits greater than 10^{10} organisms.

Avirulent strains of F. tularensis are not uncommon in the study area in spite of the fact that only two, the cottontail strain noted above and another from P. parvus have been isolated and characterized. Circumstantial evidence of their presence is provided by previous findings in the disease survey of 23 desert rodents of 9 species and 4 jack rabbits which possessed specific tularemia agglutinating antibodies and by the induction of specific antibodies in guinea pigs following the injection of 6 different tissue pools from various desert rodents and lagomorphs and 5 ectoparasite pools. One such isolate was made early in 1972 from the tissues of a jack rabbit collected at Granite Mountain; injection of 17 million organisms failed to kill white rabbits and rats and killed only 3 of 10 white mice.

The tissues of Delta cottontails have thus far failed to yield an isolate of F. tularensis of reduced virulence in spite of the

employment of special techniques. Additional work is scheduled to sample this population intensively during 1972 to obtain additional cottontail tissues for isolation attempts. Only the presence of an avirulent strain of F. tularensis can explain the high incidence of seropositives in these cottontails. However, it is also known that a fully virulent strain of the organism was circulating in this same localized population.

These findings are also important in that they cast doubt on the basic division into two groups of tularemia organisms occurring in nature which has been suggested and generally accepted by both American and Russian workers. According to this theory the two basic types of organisms are distinguished by differences in virulence and biochemical reactions, occur in different habitats and are associated with different modes of transmission and different maintenance mechanisms. One type, termed F. t. tularensis or "Type A" is thought to be restricted in distribution to the New World, is highly virulent for laboratory animals including laboratory rabbits, produces a higher fatality rate in untreated human cases (5-7%), ferments glycerol, is associated with drier habitats, and with ticks, hares, rabbits, sheep and grouse; transmission is primarily through the tick vector which is also responsible for its long term perpetuation. The second type, termed F. t. palearctica or "Type B", occurs in both the Old and New World, is relatively avirulent for laboratory rabbits, produces fatality in less than 1 per cent of untreated human cases, does not ferment glycerol, is associated with wetland habitats and in North America is characteristic of rodents (beaver, muskrats, voles) and water; this type of tularemia is believed to be a single complex dependent on water and cannibalism for transmission and entirely independent of tick transmission. The Russians agree with the concept of two types of tularemia organisms, but do not accept the hypothesis that strains of lower virulence are associated only with natural foci where small rodents and water are of dominant significance for circulation of the agent since there are numerous instances where the bacteria isolated from rodents, ticks, hares and water in several Eurasian countries from diverse habitat types have always been of the single reduced virulence type typical of Eurasia; they also note that in foci of the water type, ticks participate in circulation of the pathogenic agent and particularly in its prolonged maintenance in the intervals between epizootics.

While such generalizations have had value in synthesizing the bewildering array of data regarding tularemia epizootiology into a pattern, it should be recognized that this is simply a starting point and, as with most such generalizations, there are many exceptions and things left unexplained. Our data indicates that while there are at least the two basic types of strains present, at least on the basis of virulence, neither is limited to specific habitat types nor to a specific animal group and that within the same population of hosts both types may exist.

Bacterial Hemagglutination Test

Although other tests are available, the tube agglutination (TA) test has long been the mainstay of both human and wild animal serological investigations of tularemia. Personnel of the U.S. Public Health Service, Center for Disease Control, Zoonoses Section, Ft. Collins, Colorado, have in recent years depended more and more on the use of serological testing of sentinel carnivore species to determine the presence of both tularemia and plague activity in a given area and for the former disease have recently started employing the tularemia bacterial hemagglutination (HA) test. This test was first described in 1950 (Alexander et al, Journal of Experimental Medicine, 91:561-566) but apparently has been used very rarely as judged by literature citations, possibly because of the technical difficulty involved in preparing the polysaccharide antigen required.

The passive hemagglutination test has been reported on numerous occasions with various antigens to be more sensitive than the TA test; this difference is a direct result of the ability of the test to bring about a visible reaction. The bacterial particulate antigen employed in the TA test for tularemia was prepared from a local isolate of F. tularensis and reacts to commercial antisera and our known standards. Bacterial agglutination reactions are carried out under carefully controlled conditions of pH and ionic strength. Agglutination reactions are, in principle, neither more or less specific than other serological reactions and they present a number of difficulties. These arise because the cell surfaces contain a great number of antigenic sites capable of mediating the agglutination reaction and many of these are identical or similar in groups of different but related bacteria or cells. Therefore, to achieve a high degree of specificity it is necessary to absorb sera with cross reacting bacteria or cells or run parallel tests using the related organisms or cells. The hemagglutination system uses an extension of the classic agglutination reaction by the attachment of soluble polysaccharide (obtained from the Schu strain of F. tularensis by the method of Nicholes) to the surface of fixed red cells. This test then becomes a "passive hemagglutination" reaction. Erythrocytes can readily absorb many polysaccharides but for the attachment of proteins it is usually necessary to first treat the cells with tannic acid. As in the bacterial agglutination test, passive hemagglutination is highly sensitive and must be properly controlled. The differences seen in TA and HA reactions are probably directly related to the number of particles needed for a visible reaction. The relatively large erythrocyte coated with a thin layer of antigen serves to amplify the reaction. It is emphasized that the antibody levels measured are only in relative terms.

During 1971, a joint effort by EcoDynamics, Inc. and Dr. Bruce Hudson of the Ft. Collins CDC laboratory was made to determine the feasability of using western Utah carnivores as indicators of tularemia activity and the relative sensitivity of the HA test as compared with the TA test to detect F. tularensis antibody. After promising results were obtained from HA testing by CDC personnel of all but 4 of the 57 carnviore serum samples collected during 1971,the available carnivore serum samples collected during the 1965 through 1970 period were removed from storage and tested. The total sample tested, including 1971 specimens, was

composed of 238 samples from 115 kit foxes, 45 coyotes, 39 badgers, 32 bobcats, 4 spotted skunks and 3 house cats. This represents 91% of all the carnivores originally collected and tested from 1968 to 1971 inclusive and 84% of the kit foxes, 91% of the badgers and 100% of the coyotes and bobcats.

The results of TA testing of the total number of each of the four major carnivore species as originally reported in annual summaries together with the TA and HA results on the same specimens sampled from the particular group and year are shown in Table 15. The frequency distribution of positive reactors in the HA test for each of the four main carnivore species is shown in Table 16.

There were no TA reactors among the 33 bobcat serum samples originally tested nor among the 32 selected from this group for HA testing. In the latter test, 14 or 43.8% were reactive. Thus, the TA test failed to reveal 100% of these reactors. The reciprocal of the geometric mean titer of bobcat reactors was 33.6, the lowest of the four major carnivore species, with only 43% of the individual titers being 1:64 or greater. Experimental oral infection of two bobcats induced by feeding guinea pigs moribund from tularemia early in 1972 showed a rapid rise in HA titer to 1:2048 by the third week postinfection diminishing to 1:64 and 1:256 by the sixth week.

Among the 49 coyotes originally tested from 1965 through 1971 inclusive, 5 or 10.2% had TA titers. Three or 6.7% of the 45 sampled from this group had TA titers while 21 or 46.7% were reactive in the HA test. The TA test, then, failed to detect 18 or 85.7% of the HA reactors. The overall incidence of reactors was 7.0 times greater in the HA than in the TA test. The reciprocal of the mean titer observed in the 21 reactive coyote samples in the HA test was 95.1 with 81% of the individual titers being 1:64 or greater.

Badgers have long been considered as a sentinel species to indicate tularemia activity in our study area. Among the 47 tested from 1965 through 1971 inclusive, 15 or 31.9% were seropositive in the TA test. Thirteen or 33.3% of the sample of 39 drawn from this group were positive; 21 or 53.8% of these same specimens were reactive in the HA test. It is with this species that the HA and TA tests are in closest agreement with the TA test failing to detect only 8 or 38.1% of the HA reactors. Comparative incidence rates (33.3% by TA and 53.8% by HA) were greater by a factor of 1.6 times using the HA test. The reciprocal of the mean titer of the 21 naturally infected badgers detected by the HA test was 406.4 with 100% of the individual titers being 1:64 or greater, titers from 1:1024 to 1:4096 were not uncommon. Experimental infection experiments conducted early in 1972 have verified these high titers with HA titers ranging from 1:1024 to 1:8192 being found in badgers two weeks after feeding guinea pigs moribund from tularemia.

The kit fox is another carnivore which has been considered a tularemia sentinel over the years. Twenty-four or 12.1% of the 198 originally tested from 1965 through 1971 were reactive in the TA test as were 7 or 6.1% of the 115 sampled from this group. When tested by

Table 15. Comparison of incidence of positive reactors to *Francisella tularensis* antigen in the tube agglutination and the bacterial hemagglutination tests among carnivores, 1965-1971.

Species	Year	Agglutination Test				Hemagglutination Test on Sample	
		As Reported		Sample			
		Positive/ No. Tested	Percent Positive	Positive/ No. Tested	Percent Positive	Positive/ No. Tested	Percent Positive
Kit Fox *Vulpes macrotis*	1965	3/15	33.3	0/1	0.0	0/1	0.0
	1966	13/51	25.5	5/19	3.6	7/19	36.8
	1967	5/60	12.5	0/18	0.0	4/18	22.2
	1968	1/31	3.2	0/24	0.0	3/24	12.5
	1969	1/21	4.8	1/16	6.2	6/16	37.5
	1970	1/29	3.4	1/30	3.3	18/30	60.0
	1971	0/11	0.0	0/7	0.0	1/7	14.3
	Total	24/198	12.1	7/115	6.1	39/115	34.5
Badger *Taxidea taxus*	1965	2/6	33.3	0/3	0.0	0/3	0.0
	1966	1/4	25.0	1/2	50.0	1/2	50.0
	1967	2/2	100.0	2/2	100.0	2/2	100.0
	1968	1/2	50.0	1/1	100.0	1/1	100.0
	1969	1/9	11.1	1/7	14.3	2/7	28.6
	1970	6/16	37.5	6/16	37.5	11/16	68.8
	1971	2/8	25.0	2/8	25.0	4/8	50.0
	Total	15/47	31.9	13/39	33.3	21/39	53.8
Coyote *Canis latrans*	1965	2/4	50.0	0/1	0.0	0/1	0.0
	1966	0/5	0.0	0/4	0.0	1/4	25.0
	1967	0/2	0.0	0/2	0.0	1/2	50.0
	1968	0/1	0.0	0/1	0.0	0/1	0.0
	1969	0/9	0.0	0/9	0.0	3/9	33.3
	1970	3/15	20.0	3/15	20.0	11/15	73.4
	1971	0/13	0.0	0/13	0.0	5/13	38.5
	Total	5/49	10.2	3/45	6.7	21/45	46.7
Bobcat *Lynx rufus*	1965	0/1	0.0	0/1	0.0	0/1	0.0
	1966	0/3	0.0	0/2	0.0	0/2	0.0
	1967	0/1	0.0	0/1	0.0	0/1	0.0
	1968	---		---		---	
	1969	0/2	0.0	0/2	0.0	0/2	0.0
	1970	0/4	0.0	0/4	0.0	2/4	50.0
	1971	0/22	0.0	0/22	0.0	12/22	54.5
	Total	0/33	0.0	0/32	0.0	14/32	43.8

Table 16. Frequency distribution of antibody titers against F. tularensis polysaccharide antigen in the hemagglutination test found in four species of carnivores, 1965-1971.

Reciprocal of Titer	Badger (21)	Coyote (21)	Kit Fox (39)	Bobcat (14)
4				3
8		2	3	2
16		1	5	
32		1	8	3
64	2	6	8	2
128	3	4	6	2
256	5	4	4	
512	6	3	3	2
1024	2		2	
2048	1			
4096	2			
Geometric Mean Titer	406.4	95.1	68.7	33.6

the HA test 19 or 33.9% were reactive indicating that the TA test had failed to detect 32 or 82.0% of the HA reactors. Comparative incidence rates were 5.6 times higher in the HA test (33.9%) than in the TA test (6.1%). The reciprocal of the mean titer observed in the 39 HA reactive fox serum samples was 68.7 with 59% of the individual titers being 1:64 or greater. Experimental infection during 1972 has shown that in kit foxes HA titers rise to 1:128 to 1:1024 three weeks following ingestion of infected guinea pigs.

Spotted skunks are sampled infrequently in the routine disease surveillance program with only 9 having been collected and tested from 1965 through 1971. All were negative by the TA test. Four of these were tested by the HA test including one collected during 1969 in Iosepa, two taken in 1970 in the Dugway Mountain and South Cedar Mountains collecting areas, and one in 1971 from Government Creek. Both the 1969 and the 1971 animals were reactive exhibiting 1:32 titers.

Feral house cats are also infrequently sampled with the 17 tested from 1965 through 1971 all being negative in the TA test. Of the three tested by the HA procedure, one taken at Callao in 1971 was reactive with a titer of 1:128. A human tularemia case occurred in Callao during 1971 with the date of onset being August 1. The only exposure history of this case was the bite of a kitten. This kitten disappeared shortly after biting the boy but its mother was located and a blood sample drawn in November. It was this cat that gave the HA tularemia reaction.

Perusal of Table 15 shows that there has been an increased number of carnivores of all species except the kit fox sampled during the last two years; this is the result of deliberate effort to obtain such specimens as sentinels. Even so, comparison of annual or geographic incidence rates is difficult due to the small sample size. Another factor which makes comparisons among earlier years and more recent years difficult is the fact that many of the older samples have been frozen and thawed several times, purposely for retesting or inadvertently because of power outages, thus possibly contributing to a reduction in antibody level to the point where an originally positive sample would test negative. Also, not all of the original samples were available for HA testing since some samples had been depleted; this was especially true of positive specimens since these were previously selected for re-testing or for use as controls. It is with these reservations in mind that the following annual and geographic incidence comparisons must be viewed.

Based on the TA test results of the entire sample for each year, tularemia activity in the kit fox has declined steadily since 1965 but has shown no definite trends in either the badger or coyote. On the other hand, results of HA testing of the samples available from each year suggest a high level of tularemia activity in 1970 and/or 1971. Of the four primary carnivore species, 55.6% of the 115 collected during these two years were seropositive by HA whereas the comparative figure for the 1965-69 period is significantly lower at 26.7% of 116. During 1970, 64.6% of the 65 carnivores were HA reactive while during 1971 44.0% of 50 were. By individual species, the percentage that the total number of reactors collected during 1970-71 is to the total number detected

during the 7 years and compared with the percentage that the 1970-71 sample is to the total number sampled over the 7 year period is as follows: bobcats, 100.0% of reactors and 81.3% of sample; coyotes, 76.2% and 62.2%; badgers, 71.4% and 61.5%; and foxes, 48.7% and 32.1%. In all species the percentage of reactors found during these two years is greater than the percentage sampled by a factor ranging from 1.2 to 1.5. This ratio was greater in 1970 than in 1971 for coyotes, badgers and kit foxes and approximately equal in both years among bobcats. The apparent higher incidence in the last two years is consistent with the high rabbit populations which have been present in the study area during this period.

The incidence of HA reactors among these carnivores related to the geographic area from which they came is shown for the entire 1965-71 period in Table 17 and for 1971 alone in Table 18. It will be noted that incidence of reactors is widespread with positive individuals being found in 15 of the 21 collecting areas sampled; the six negative areas each had no more than two samples tested. Since carnivores are not systematically collected from each area, incidence seems more correlated with collecting effort than with particular geographic foci of infection.

Analysis of biological data concerning the individual carnivore specimens failed to reveal conclusive trends. Reactors were taken at all seasons of the year and were found among all age categories from the very young to very old. There was also no correlation between the ages of reactors and the magnitude of their titer.

In summary, the HA test is much more sensitive in detecting previous exposure to F. tularensis among carnivores than the TA test. Incidence rates for each of the four major carnivore species, based on the 1965-71 sample, were significantly higher than those determined by the TA test with the number of reactors being greater by a factor of 1.6 for badgers, 5.6 for kit fox, 7.0 for coyotes, and infinitely higher for bobcats since in this species 14 reactors were detected by the HA test whereas none were found in the TA test. During 1971 alone, only two animals (both badgers) were reactive in the TA test whereas 24 were detected using the HA system (12 bobcats, 5 coyotes, 4 badgers, and one each kit fox, house cat and spotted skunk.) This data indicates that tularemia activity is much more widespread geographically and much more prevalent than has been indicated by the results of previous serological surveys and by the number of isolations obtained from ectoparasites and animal tissues. This is not particularly unexpected in view of the fact that, due to their extreme susceptibility to virulent strains of F. tularensis, most rodents and lagomorphs having exposure to the organism will die quickly and thus not be available for sampling in routine disease surveillance activities. The carnivores, on the other hand, being refractory to tularemia infection and continually sampling the prey population (and also the prey's ectoparasites) are undoubtedly much better indicators of disease activity. The relatively long life of the carnivores and the large geographic area over which they roam makes it difficult, however, to define the time and place of disease activity.

Table 17. Incidence of reactors against F. tularensis polysaccharide antigen in the HA test among carnivores sampled 1965-1971, by collecting area. Number of reactors/number tested.

Collecting Area	Kit Fox	Bobcat	Coyote	Badger	House Cat	Spotted Skunk	Total
Old Lincoln Highway	1/2			2/2			3/4
Wig Mountain			4/8	0/1			4/9
Camelback Mountain	19/64	1/2	5/12	2/7	0/1		27/86
Dugway Valley	3/8		1/3	4/5			8/16
Granite Mountain		1/1					1/1
South Cedar Mountains	2/6	5/9	2/2	5/8		0/1	14/26
Government Creek	7/20	4/10	3/9	3/9		1/1	18/49
Iosepa			0/1			1/1	1/2
Condie	2/2	3/7	4/4				9/13
Big Davis Mountain	4/6						4/6
Erickson Pass	0/2						0/2
Dugway Mountains				2/2		0/1	2/3
Trout Creek	0/1						0/1
Callao	0/2	0/1	0/1	2/2	1/2		3/8
Lakeside			2/3				2/3
East Wendover			0/1				0/1
South Wendover	1/2						1/2
West Wendover				0/1			0/1
Duchesne				1/2			1/2
Delta		0/2					0/2
South Idaho			0/1				0/1
Totals	39/115	14/32	21/45	21/39	1/3	2/4	98/238

Table 18. Incidence of reactors against F. tularensis polysaccharide antigen in the HA test among carnivores sampled during 1971, by collecting area. Number of reactors/number tested.

Collecting Area	Kit Fox	Bobcat	Coyote	Badger	House Cat	Spotted Skunk	Total
Old Lincoln Highway	0/1			1/1			1/2
Camelback Mountain	0/4	1/2	0/5	0/1			1/12
Dugway Valley	1/2						1/2
South Cedar Mountains		5/5	1/1				6/6
Government Creek		3/8	2/5	3/6		1/1	9/20
Condie		3/7	2/2				5/9
Callao					1/2		1/2
Totals	1/7	12/22	5/13	4/8	1/2	1/1	24/53

Each and every carnivore serum sample which exhibited a TA titer was also reactive in the HA test, generally at titers from 1-4 dilutions higher in the latter. The specificity of the HA system has been tested both in our laboratory and by the CDC Ft. Collins laboratory and found to be high. Experimental oral infection of badgers, kit foxes, coyotes and bobcats conducted early in 1972 has provided further evidence of the specificity of the test and is providing data on the magnitude and duration of antibody response. The HA test is now being conducted routinely in the EcoDynamics laboratories; repeat testing of numerous samples has shown excellent correlation of results between the two laboratories.

It was noted in a previous section that a high rate of reactors in the TA test for tularemia was detected among cottontails from Delta with 13 or 33.3% of 39 yielding titers ranging from 1:40 to 1:640. There was sufficient serum from 11 of the 13 reactors to allow testing by the Ft. Collins Laboratory of CDC using the HA test. Each of the 11 was reactive at titers ranging from 1:128 to 1:4096. In addition, among the 25 cottontails in this sample which were non-reactive in the TA test, four were reactive using the HA test at low titers of 1:8, 1:12, 1:64 and 1:96. The significance of these low titers is not clear but the probability is that they represent animals which had exposure to tularemia at a more distant time in the past than most of the cottontails in this population. If these are valid indicators, then the number of animals in this sample which had prior exposure to the organism would increase to at least 17 or 43.6% of 39.

Forty sheep sera were tested for tularemia antibody using the HA test to determine if this test could be used with that species in place of the TA test. The sera selected were from a pool of some 400 and contained TA negatives as well as positives. It was hoped the HA test would be more sensitive than the TA test and hence more closely estimate the true tularemia infection rate of sheep. The results obtained were inconclusive. All of the sera tested reacted in the test at a titer of 1:32 or greater except for one. Nonspecific reactions were also noted which made the drawing of any conclusions impossible. Three of the sera had reactions which could be interpreted as being positive.

An attempt has been made to obtain known positive sheep sera so that basic information on the sensitivity of the HA test for detection of tularemia antibody may be determined. Studies are also being conducted which will lead to the elimination of the nonspecific reactions. Other livestock sera have not been investigated to date using the HA system but are being anticipated.

Yersinia pestis (Plague)

Results of Disease Surveillance

During 1971 the only evidence of plague activity detected by standard diagnostic methods was the isolation of the organism from fleas parasitizing chipmunks in Bryce Canyon National Park. Comparisons of plague activity among species found positive from 1967 through 1971 and by animal groupings are found in Tables 19 and 20.

The isolation referred to (designated 71 I 356) came from a pool of 17 Monopsyllus eumolpi fleas collected from 9 E. minimus (71 I 356, 364-368, 370, 372, 373) on September 9, 1971 at the North Campground area of Bryce Canyon National Park. The isolation was made in two guinea pigs weighing 350-400 gms. which were both dead eight days following injection of the flea pool. Both animals had enlarged necrotic spleens with numerous spots and enlarged lymph nodes at the site of injection. Livers and lungs appeared normal. Organisms were readily isolated from the spleens of each. The organisms isolated were sensitive to Y. pestis bacteriophage when incubated at 25° and 37° and were agglutinated by Y. pestis antiserum. Verification was obtained from a culture of this isolate sent to the Center for Disease Control, USPHS, Ft. Collins, Colorado. Virulence studies are not yet complete but tentative results indicate this strain is of full virulence.

This was the 14th time evidence of plague has been discovered at Bryce Canyon since annual one-week collecting trips have been made, usually in September, beginning in 1965. From 1965 through 1969, nine isolations of the organisms were made (from E. minimus and E. umbrinus and their most common flea M. eumolpi and once from the tissues of P. maniculatus) and four chipmunk serological reactors were detected in the plague complement fixation test. No evidence of plague activity was revealed during 1970.

The 1971 Bryce Canyon sample consisted of 209 rodents (83 E. umbrinus, 51 P. maniculatus, 40 E. minimus, 32 Spermophilus lateralis and 3 Lagurus curtatus) and the 292 fleas associated with these hosts collected from 10 areas within the Park. At the North Campground site, where evidence of plague had been detected three times previously within one-quarter mile, 22 rodents consisting of 11 E. minimus, four each E. umbrinus and S. lateralis and three P. maniculatus were collected and tested as were the 22 fleas associated with them. The flea index was not high, averaging 1.5 fleas per E. minimus. None of the tissues of these North Campground rodents yielded evidence of plague nor were any serological reactors detected.

Serological testing of certain species of Eutamias by the CF test has always presented difficulties since the serum of a large percentage of these animals is anticomplementary making reliable tests of low-titered serum almost impossible to achieve. Of those sampled at Bryce Canyon during 1971, 54.2% of the E. umbrinus and 45.0% of the E. minumus were anticomplementary. Thus, the failure to detect CF seropositives among these chipmunks does not necessarily indicate a lack of animals possessing antibodies to Y. pestis and greatly reduces the sensitivity and completeness of the plague survey.

With two exceptions, all evidence of plague at Bryce Canyon has been in an area 1.5 miles long and 0.25 miles wide in the center of visitor activity,

Table 19. Incidence of Yersinia pestis in wildlife specimens of the Great Basin region as determined by specific complement fixing antibodies and isolation of the organism, 1967-1971.

Species	1967 Positive/Total Isolation	%	1968 Positive/Total Isolation	%	1969 Positive/Total Isolation	%	1970 Positive/Total Isolation	%	1971 Positive/Total Isolation	%
RODENTS										
Eutamias minimus	0/133	-	3/143	2.9	0/126	-	0/176	-	0/176	-
	(1)	0.8	(1)	0.7					1*	0.6
E. umbrinus	0/93	-	1/47	2.1	0/46	-	0/111	-	0/83	-
			1*	2.1						
Peromyscus	0/944	-	1/1568	0.06	3/1887	0.2	1/1698	0.06	0/1732	-
maniculatus	2*	0.2			(2)	0.1	(1) 1	0.11		
Microtus	0/13	-	1/85	1.2	0/46	-	0/2	-	0/2	-
longicaudas	(2)	15.4	(1) 1*	2.4	2*	6.5				
Others	0/1771 (25 Species)	-	0/1261 (24 Species)	-	0/1397 (22 Species)	-	0/1419 (20 Species)	-	0/1193 (18 Species)	-
Total	0/2954	-	6/3104	0.19	3/3502	0.08	1/3406	0.02	0/3186	-
	(3) 2*	0.16	(2) 2*	0.12	(3) 2*	0.14	(1) 1	0.58	1*	0.03
LAGOMORPHS										
All species	0/866 (5 Species)	-	0/1340 (5 Species)	-	0/1814 (4 Species)	-	0/1008 (2 Species)	-	0/1059 (2 Species)	-
OTHER VERTEBRATES										
Vulpes macrotis	0/40	-	0/31	-	1/21	4.76	0/29	-	0/11	-
Others	0/39 (7 Species)	-	0/54 (5 Species)	-	0/78 (7 Species)	-	0/61 (7 Species)	-	0/57 (6 Species)	-
Total	0/79	-	0/85	-	1/99	1.0	0/90	-	0/68	-
AVES										
All species	0/616 (26 Species)	-	0/544 (28 Species)	-	0/444 (31 Species)	-	0/19 (4 Species)	-	0/3 (3 Species)	-

* Indicates isolation of the organism from ectoparasites

1 Indicates conversion titer in indicator animals (guinea pig)

( ) Indicates isolation of the organism from tissue

Table 20. Incidence of *Yersinia pestis* in wildlife specimens of the Great Basin region as determined by specific complement fixing antibodies and isolation of the organism, 1967-1971 inclusive

Year	Number Positive	Number Tested	Percent Positive	Areas yielding positive specimens
				RODENTS
1967	(3) 2*	2954	0.16	Callao, Bryce Canyon
1968	6	3104	0.19	Callao, Bryce Canyon
	(2) 2*		0.12	Callao, Bryce Canyon
1969	3	3502	0.08	Stansbury, Deep Creek
	(3) 2*		0.14	Callao, Stansbury, Bryce Canyon
1970	1	3406	0.02	Erickson Pass
	(1)		0.02	Camelback Mountain
	1		0.02	Fish Springs
1971	1*	3186	0.03	Bryce Canyon
				LAGOMORPHS
1967	0	866	-	----
1968	0	1340	-	----
1969	0	1814	-	----
1970	0	1008	-	----
1971	0	1059	-	----
				OTHER VERTEBRATES
1967	0	79	-	----
1968	0	85	-	----
1969	1	99	1.00	Government Creek
1970	0	90	-	----
1971	0	68	-	----
				AVES
1967	0	616	-	----
1968	0	544	-	----
1969	0	444	-	----
1970	0	19	-	----
1971	0	3	-	----

1 Indicates the number of serological positive wildlife sera

1* Indicates isolation of the organism from ectoparasites

1 Indicates indicator (guinea pig) animal conversion titers

() Indicates isolation of the organism from tissue

service areas, campgrounds, lodging and permanent employee residences near the Park entrance. The two exceptions were an isolation from fleas at Natural Bridge, 7 miles southwest, and a seropositive from Rainbow Point, 10 miles south-southwest of this main focus.

Insecticide bait-boxes employing 5% Malathion dust were first set out by Park personnel at strategic locations in the summer of 1967 and have been maintained during the spring and summer each year since as part of a program to reduce the potential for human involvement. These have reduced flea populations significantly but not to the point where it has eliminated plague transmission among the rodents since the 1971 isolate and most of those made in previous years have come from areas where this control method has been employed.

The basic maintenance cycle of plague at Bryce Canyon involves the two species of chipmunks and their dominant flea M. eumolpi. The disease seems firmly entrenched in the wildlife and undoubtedly will continue despite the attempts to control same with insecticide bait-boxes. Since most plague activity has been detected in areas of high tourist activity, a definite potential for human involvement does exist and can be expected to persist. The willingness with which M. eumolpi will transfer to and bite humans makes this threat more than a remote possibility. Continued use of bait-boxes and publicity warning visitors of the danger should keep the threat minimal.

As part of the routine disease surveillance program, two trapping sites were set one mile apart on April 15, 1971 in the Dugway Valley collecting area near the south boundary fence of Dugway Proving Ground at a location 12 miles southwest of Ditto Technical Center. Captured and tested were 8 deer mice, 4 least chipmunks and one each Ord kangaroo rat and harvest mouse. No evidence of disease was obtained from the tissues or ectoparasites of these animals. One chipmunk, (71 D 225), a pregnant adult female, did show a 1:8 titer against Y. pestis antigen in the CF screen-testing procedure; upon retesting, however, this serum sample was anticomplementary. Another chipmunk, (71 D 226), this one an adult male from the adjoining trapping plot, was anticomplementary during the initial screen test. Both of these samples were sent to the Center for Disease Control, USPHS, Ft. Collins, Colorado, as part of a co-operative project (described in the next section of this report) to compare the relative sensitivity of the CF and the passive hemagglutination (HA) tests for Y. pestis. Both samples yielded significant HA titers with the first animal being 1:48 and the second 1:64.

The fleas from these two animals or from others on these two trapping plots were not identified or injected into indicator animals but it is almost certain that the three fleas obtained from the two infested chipmunks were M. eumolpi. As noted above, this flea is commonly involved in plague transmission among chipmunks. Plague activity has previously been reported from areas within 10 miles of the site implicated during 1971.

In early September, two sites in Thom's Creek Canyon of the Deep Creek Mountain Range which had yielded evidence of plague on several previous occasions were sampled. No evidence of plague was obtained from the tissues or sera of the 39 P. maniculatus sampled or from the injection of the 38 fleas infesting these hosts.

Passive Hemagglutination Test

In recent years it has become generally agreed that the passive hemagglutination test is the technique of choice for serological investigations of wild animal populations. Both the HA and the CF test employ the same Fraction I envelope antigen of Y. pestis; unfortunately, this antigen is not available commercially and must be prepared. The majority of investigators feel that the HA test is superior to the CF test on the basis of sensitivity, ease of performance, and the fact that the frequent occurrence of anti-complementary activity in wild animal sera often presents difficulties in the CF test. There is also evidence that positive reactions persist for longer periods of time in the HA test than in the CF test; this would be of particular importance in wild animals such as carnivores which have relatively long lives.

Wild carnivores and dogs have been utilized with increased frequency in recent years as monitors of the degree and geographic localization of plague activity in prey species, primarily in conjunction with assessing plague hazard to humans or during epidemiological investigations of human cases. These animals, being relatively resistant to plague, acquire contact with the organism primarily through ingesting the flesh and/or fleas of the prey population they are continually sampling. The assumed greater probability of individuals of a prey species which are sick or dying of disease of being captured by a predator would seem to make carnivores even better sentinels of plague activity.

During 1971, carnivore serum samples obtained over several years as part of routine disease surveillance activities in western Utah, all of which had been tested by the CF test, were sent to Dr. Bruce Hudson, Center for Disease Control, USPHS, Ft. Collins, Colorado, for testing by the HA technique to determine the relative sensitivity of the two methods. The HA technique is described in the literature (Goldenberg, M.I., Hudson, B.W., and Kar man, L., Passive hemagglutination using Yersinia (Pasteurella) pestis fraction I antigen, APHA, 1970, Diagnostic Procedures for Bacterial, Mycotic and Parasitic Infections, Fifth Edition, pp. 434-435), but a number of unpublished modifications and refinements have been made to this published account. Dr. Hudson provided us with same during a visit to his laboratory made especially to learn the techniques of conducting this test.

The same carnivore serum samples which were tested for HA antibodies to F. tularensis were also tested by the HA technique for antibodies against Y. pestis. As noted earlier, the 238 samples were collected from 1965 through 1971 inclusive and included 115 kit foxes, 45 coyotes, 39 badgers, 32 bobcats, four spotted skunks and three house cats. These represented 91% of all the carnivores originally collected and tested from 1968 to 1971 inclusive and 84% of the kit foxes, 91% of the badgers and 100% of the coyotes and bobcats. The results of CF testing of the total number of each of the four major carnivore species as originally reported in annual summaries together with the HA results on the sample drawn from this total by year are shown in Table 21. It will be noted that only a single sample (a kit fox collected in 1969) was determined to be positive by the CF test among the 327 samples of the four major species originally tested. This particular sample was not available for HA analysis. There were no CF reactors among the 17 samples from domestic cats or nine samples from spotted skunks originally tested although these are not shown in the table.

Table 21. Comparison of positive reactors to Yersinia pestis antigen in the complement fixation and passive hemagglutination tests among carnivores 1965-1971.

Species	Year	Complement Fixation Test Results Reported		Passive Hemagglutination Test on Sample		Species	Year	Complement Fixation Test Results Reported		Passive Hemagglutination Test on Sample	
		Positive/ No. Tested	Percent Positive	Positive/ No. Tested	Percent Positive			Positive/ No. Tested	Percent Positive	Positive/ No. Tested	Percent Positive
Kit Fox *Vulpes macrotis*	1965	0/15	0.0	0/1	0.0	Coyote *Canis latrans*	1965	0/4	0.0	0/1	0.0
	1966	0/51	0.0	0/19	0.0		1966	0/5	0.0	0/4	0.0
	1967	0/40	0.0	0/18	0.0		1967	0/2	0.0	0/2	0.0
	1968	0/31	0.0	0/24	0.0		1968	0/1	0.0	0/1	0.0
	1969	1/21	4.8	0/16	0.0		1969	0/9	0.0	0/9	0.0
	1970	0/29	0.0	0/30	0.0		1970	0/15	0.0	3/15	20.0
	1971	0/11	0.0	3/7	42.9		1971	0/13	0.0	2/13	15.4
Total		1/198	0.5	3/115	2.6	Total		0/49	0.0	5/45	11.1
Badger *Taxidea taxus*	1965	0/6	0.0	0/3	0.0	Bobcat *Lynx rufus*	1965	0/1	0.0	0/1	0.0
	1966	0/4	0.0	0/2	0.0		1966	0/3	0.0	0/2	0.0
	1967	0/2	0.0	1/2	50.0		1967	0/1	0.0	1/1	100.0
	1968	0/2	0.0	0/1	0.0		1968	---	---	---	---
	1969	0/9	0.0	0/7	0.0		1969	0/2	0.0	0/2	0.0
	1970	0/16	0.0	0/16	0.0		1970	0/4	0.0	0/4	0.0
	1971	0/8	0.0	1/8	12.5		1971	0/22	0.0	4/22	18.2
Total		0/47	0.0	2/39	5.3	Total		0/33	0.0	5/32	15.6

HA testing yielded 15 positive specimens including five coyotes, five bobcats, three kit foxes and two badgers. The overall percentage of reactors in the sample for the seven years was 15.6% for bobcats, 11.1% for coyotes, 5.3% among badgers and 2.6% among kit foxes. Positive specimens are listed in Table 22 with their identifying sample number which indicates the year and month of collection, the geographic collecting area, and the HA titer determined.

Although one is somewhat hesitant to make comparisons of incidence between more recent and earlier years because the samples from earlier years do not represent the entire sample originally tested and also because of the possibility (unconfirmed) that antibody may deteriorate with long storage and freezing and thawing, it does appear that plague activity increased significantly among carnivores in 1971. Ten or 66.7% of the 15 carnivore seropositives were from animals collected in 1971 whereas only 21.6% of the total carnivore samples tested were collected in that year. By individual species the total number of seropositives collected in 1971 as related to the total number of seropositives detected during the 1965-1971 period and compared with the percentage that the 1971 sample size is to the total number of samples for that species is as follows: Bobcats, 4 of the 5 (80.0%) reactors vs. 68.8% of the total bobcat sample; badgers, 1 of 2 (50.0%) vs. 20.5%; kit foxes, 3 of the 3 (100.0%) vs. 6.1% of the kit fox sample; and coyotes, 2 of 5 (40.0%) vs. 28.9% of the sample. Thus, the observed number of reactors detected during 1971 was 3.1 times greater in the carnivore sample as a whole than would be expected on the basis of random distribution over the years and varied by individual species by a factor ranging from 1.2 to 16.4 times greater than expected. Coyotes also showed a high reactor rate in 1970 when 3 of the 5 seropositives were detected (60.0%) among the 15 or 33.3% of the total coyote sample tested. The incidence rates of seropositives during 1971 were 42.9% of the kit foxes, 18.2% of bobcats, 15.4% of coyotes and 12.5% of badgers. The trend toward increased plague incidence among carnivores has continued into 1972 with 21 carnivores (10 bobcats, 5 kit foxes, 4 badgers, and one each spotted skunk and coyote) collected from January through April having significant HA antibody titers.

The incidence of seropositive carnivores by species in relation to sample size by collecting area is shown in Table 23 for the entire 1965-1971 period and for 1971 alone in Table 24. Seven areas were involved from 1965-1971 with Camelback Mountain, Condie and Governemnt Creek yielding the greatest number of reactors (11 of the 15 total); these areas, however, were the ones from which the greatest number of samples were obtained. Only in Condie does the incidence appear significantly higher than might be expected with two of the seven bobcats and two of the four coyotes sampled being reactive. In four of the areas only one species exhibited evidence of plague activity while reactors were detected in three species in Government Creek and two each in Camelback Mountain and Condie. During 1971, seropositive carnivores were obtained from four areas with Camelback Mountain and Government Creek yielding seven of the ten reactors.

No strong correlations between positive specimens and age, sex or time of collection or between age and titer could be determined. Reactors were found among all age groups from the very young to the very old. Two litter-mate kit foxes sampled at their den in June 1971 when they were three months of age were both positive with HA titers of 1:16 and 1:32 respectively. The latter animal was recaptured at 10 months of age on January 20, 1972, 226 days after the initial blood sample was drawn, and again exhibited a titer of 1:32.

Table 22. Evidence of *Yersinia pestis* in carnivores sampled 1965-1971 in the Great Basin as determined by specific antibodies to F1 antigen in the passive hemagglutination test.

Species	Host Number	Area	Reciprocal of titer
Taxidea taxus	67G 37	Dugway Valley	16
	71L 135	Government Creek	128
Canis latrans	70A 94	Wig Mountain	16
	70K 169	Condie	32
	70K 170	Condie	32
	71L 29	Government Creek	32
	71L 132	Camelback Mountain	16
Vulpes macrotis	71F 63	Camelback Mountain	32
	71F 64	Camelback Mountain	16
	71K 110	Camelback Mountain	96
Lynx rufus	67B 107	Callao	64
	71A 156	South Cedar Mountain	32
	71B 97	Condie	64
	71B 201	Condie	64
	71L 114	Government Creek	16

Table 23. Incidence of reactors to Yersinia pestis F1 antigen in the passive hemagglutination test among carnivores sampled 1965-71, by collecting area. Number of reactors/number tested.

Collecting Area	Kit Fox	Bobcat	Coyote	Badger	House Cat	Spotted Skunk	Total
Old Lincoln Highway	0/2			0/2			0/4
Wig Mountain			1/8	0/1			1/9
Camelback Mountain	3/64	0/2	1/12	0/7	0/1		4/86
Dugway Valley	0/8		0/3	1/5			1/16
Granite Mountain		0/1					0/1
South Cedar Mountains	0/6	1/9	0/2	0/8		0/1	1/26
Government Creek	0/20	1/10	1/9	1/9		0/1	3/49
Iosepa			0/1			0/1	0/2
Condie	0/2	2/7	2/4				4/13
Big Davis Mountain	0/6						0/6
Erickson Pass	0/2						0/2
Dugway Mountains				0/2		0/1	0/3
Trout Creek	0/1						0/1
Callao	0/2	1/1	0/1	0/2	0/2		1/8
Lakeside			0/3				0/3
East Wendover			0/1				0/1
South Wendover	0/2						0/2
West Wendover				0/1			0/1
Duchesne				0/2			0/2
Delta		0/2					0/2
South Idaho			0/1				0/1
Totals	3/115	5/32	5/45	2/39	0/3	0/4	15/238

Table 24. Incidence of reactors to Yersinia pestis F1 antigen in the passive hemagglutination test among carnivores sampled during 1971, by collecting area. Number of reactors/number tested.

Collecting area	Kit Fox	Bobcat	Coyote	Badger	House Cat	Spotted Skunk	Total
Old Lincoln Highway	0/1			0/1			0/2
Camelback Mountain	3/4	0/2	1/5	0/1			4/12
Dugway Valley	0/2						0/2
South Cedar Mountains		1/5	0/1				1/6
Government Creek		1/8	1/5	1/6		0/1	3/20
Condie		2/7	0/2				2/9
Callao					0/2		0/2
Totals	3/7	4/22	2/13	1/8	0/2	0/1	10/53

Six of the 15 carnivore serum samples which gave positive results in the HA test for plague also yielded significant titers in the HA test for tularemia. These included three coyotes (70A094, 70K169, 70K170), two bobcats (71A156, 71B097), and one badger (67G037). Titers in the tularemia test were generally 1-4 tubes higher than in the plague test with the exception of the badger which had a 1:16 plague titer and a 1:2048 tularemia titer. Extensive investigations by the CDC, Ft. Collins Laboratory, has shown that there is no cross reaction in the HA test between these two organisms. Thus, these animals can be safely assumed to have had contact with both pathogens.

The results of HA testing of carnivore serum samples reported here confirm the findings of others and demonstrate the much greater sensitivity of the HA test over the CF test. With the co-operation and advice of the CDC Ft. Collins Laboratory, the technique of the HA test has been mastered and it can now be conducted with confidence in the EcoDynamics Laboratory. It is anticipated that during 1972, rodent serum samples collected in previous years from highly suspect areas such as Bryce Canyon National Park and the Deep Creek Mountains will be tested by this technique to give a more complete and realistic insight into plague epizootiology.

Coxiella burnetii (Q Fever)

The evidence of Q fever activity in samples collected in 1971 is shown in Table 25 and consists of two serologically reactive rodents from Dugway Valley and two jack rabbits, one each from Gold Hill and Iosepa. Comparisons of this year's findings with the four previous years by species, animal grouping and in domestic livestock may be made by reference to Tables 26 , 27 , and 28 .

Table 25. Incidence of Coxiella burnetii in wildlife specimens of the Great Basin region as determined by specific complement fixing antibodies 1971.

Species	Host Number	Area	Reciprocal of Titer
RODENTS			
Peromyscus maniculatus	71D 227	Dugway Valley	16
Eutamias minimus	71F 204	Dugway Valley	16
LAGOMORPHS			
Lepus californicus	71C 297	Gold Hill	64
L. californicus	71H 7	Iosepa	16

Additional studies conducted on those 1970 tissue pools which resulted in the induction of complement fixing antibodies in indicator animals did not yield any isolations of C. burnetii. Blind passages in mice and guinea pigs employing the original tissues and/or indicator animal tissue were conducted with negative results.

Detectable activity of C. burnetii in the wildlife of the local region has continued to decline drastically since the epizootic proporations reached during 1960. At that time more than 30 "isolations" were made from tissues and over 20 made from ectoparasites of rodents and lagomorphs in a single year. The great majority of these and subsequent evidences of the pathogen in tissues or ectoparasites were reported as "isolations" but actually consisted of the serological conversion of guinea pigs. During this same period of high Q fever activity, although there was some difficulty with false positives at that time, revised testing indicated that serological reactor rates of 5-25% within each of the major rodent and lagomorph species were not uncommon. No isolations or guinea pig conversions have resulted from the examination of ectoparasites since 1964 and the last from jack rabbit tissue was in 1966. A few isolates from rodent tissues, ranging from none to 11 were made each year from 1964 to 1969, these being primarily from D. microps, D. ordii, P. maniculatus and A. leucurus.

Table 26. Incidence of *Coxiella burnetii* in wildlife specimens of the Great Basin region as determined by specific complement fixing antibodies and isolation of the organism, 1967-1971.

Species	1967 Positive/Total Isolation	%	1968 Positive/Total Isolation	%	1969 Positive/Total Isolation	%	1970 Positive/Total Isolation	%	1971 Positive/Total Isolation	%
RODENTS										
Eutamias minimus	0/133	-	0/143	-	0/126	-	0/176	-	1/176	0.6
	2*	1.5								
Ammospermophilus	2/430	0.5	0/157	-	0/99	-	0/218	-	0/162	-
leucurus	4*	0.9					1	0.5		
Perognathus formosus	0/145	-	0/149	-	0/114	-	0/91	-	0/161	-
			1*	0.7						
Dipodomys ordii	0/470	-	0/315	-	0/336	-	1/326	0.3	0/183	-
			2*	0.6						
D. microps	1/153	0.7	0/48	-	0/64	-	0/85	-	0/23	-
	4*	2.6	1*	2.1			1	1.2		
Peromyscus crinitus	0/55	-	0/86	-	0/122	-	0/128	-	0/140	-
							1	0.8		
P. maniculatus	1**/944	-	1/1568	0.06	1/887	0.05	1/1698	0.06	1/1732	0.05
			1*	0.06			2	0.1		
Onychomys	0/8	-	0/13	-	0/14	-	0/8	-	0/4	-
leucogaster	1*	12.5								
Rattus norvegicus	1/32	3.1	0/51	-	-	-	-	-	-	-
Others	0/584 (20 Species)	-	0/574 (20 Species)	-	0/740 (18 Species)	-	0/576 (16 Species)	-	0/605 (14 Species)	-
Total	4/2954	0.13	1/3104	0.03	1/3502	0.02	2/3406	0.06	2/3186	0.06
	11*	0.37	5*	0.16			5	0.14		
LAGOMORPHS										
Lepus californicus	0/837	-	0/1294	-	4/1772	0.2	3/991	0.3	2/984	0.2
Others	0/29 (4 Species)	-	0/46 (4 Species)	-	0/92 (3 Species)	-	0/17 (1 Species)	-	0/75 (1 Species)	-
Total	0/866	-	0/1340	-	4/1814	0.22	3/1008	0.3	2/1059	0.18
OTHER VERTEBRATES										
All species	0/79 (8 Species)	-	0/85 (6 Species)	-	0/99 (8 Species)	-	0/90 (8 Species)	-	0/68 (8 Species)	-
BIRDS										
All species	0/616 (25 Species)	-	0/544 (28 Species)	-	0/444 (31 Species)	-	0/19 (4 Species)	-	0/3 (3 Species)	-

* Indicates isolation of organism from tissue

1 Conversion titer in indicator animals (guinea pigs) inoculated with tissue

** Not included in totals

Table 7. Incidence of Coxiella burnetii in wildlife specimens of the Great Basin region as determined by specific complement fixing antibodies and isolation of the organism, 1967-1971.

Year	Number Positive	Number Tested	Percent Positive	Areas yielding positive specimens
				RODENTS
1967	4	3954	0.13	Old Lincoln Highway, GPI-3, Stansbury
	11*		0.37	Old Lincoln Highway, Camelback Mountain, GPI-3, Government Creek, Fish Springs, Bryce Canyon
1968	1	3104	0.03	Government Creek
	5*		0.16	South Cedar Mountain, Fish Springs, East Wendover, Bryce Canyon
1969	1	3502	0.02	Callao
1970	2	3406	0.06	Camelback Mountain, Government Creek
	5		0.14	Granite Mountain, Government Creek, Dugway Mountain, Trout Creek, North Wendover
1971	2	3186	0.06	Dugway Valley
				LAGOMORPHS
1967	0	866	-	----
1968	0	1340	-	----
1969	4	1814	0.22	Trout Creek, Twin Falls
1970	3	1008	0.3	Erickson Pass, Twin Falls, Old Lincoln Highway
1971	2	1059	0.18	Gold Hill, Ioseps
				OTHER VERTEBRATES
1967	0	79	-	----
1968	0	85	-	----
1969	0	99	-	----
1970	0	90	-	----
1971	0	68	-	----
				AVES
1967	0	616	-	----
1968	0	544	-	----
1969	0	444	-	----
1970	0	19	-	----
1971	0	3	-	----

1 Indicates the number of serological positive wildlife sera

1* Indicates isolation of the organism from tissues

1 Indicates indicator animal (guinea pig) conversion titers

Table 28. Incidence of Coxiella burnetii complement fixing antibodies in domestic livestock sera collected in the Great Salt Lake Desert region 1967-1971.

Year	Positive 1:16 or >	Number Tested	Percent Positive	Areas yielding positive specimens
				CATTLE
1967	0	684	-	----
1968	0	73	-	----
1969	6	521	1.15	Callao
1970	0	483	-	----
1971	0	225	-	----
				SHEEP
1967	0	971	-	----
1970	3	1225	0.2	Big Davis Mountain, Skull Valley
1971	0	1684	-	----
				HORSES
1967	0	18	-	----
				SWINE
1967	0	8	-	----
				GOATS
1971	0	6	-	----

Lepus californicus, considered an important amplifier in Q fever epizootiology, has exhibited a stable, low incidence of seropositives since 1966 with the reactor rate in locally-collected animals being 0.5%, 0.0%, 0.0% 0.2%, 0.3%, and 0.3% from 1966-71 inclusive. During the same years, the numbers of rodent seropositives have also remained low at 1,5,1,1,2, and 2 with species incidence rates in the major species generally less than 1%. It appears that Q fever incidence in wildlife of the local area is related to factors other than jack rabbit abundance since there has been no increase in activity of this disease to correlate with the greatly increased jack rabbit populations of the last several years.

As in previous years, no correlations could be made between reactive individual animals and biological data. The collecting sites were widespread and reactive individuals were taken in March, April, June, and August. The seropositive deer mouse was 78 days of age and, as such, was in one of the most frequently collected age groups of this species. Least chipmunks cannot be aged this accurately, but the reactive animal was an adult. Both of the reactive jack rabbits were females, one of which was pregnant and were both adults in the most frequently collected age group.

The failure to detect serologically positive cattle is not inconsistent with previous results since in three prior years since sampling began in 1962, no reactors were found. Except for two years, 1962 and 1965, when 3.8% and 4.6% respectively, of the samples were positive, incidence rates have been between 0.6-1.2%. The zero reactor rate among sheep is the same as was encountered in 1967 and is not significantly different from the 1970 rate of 0.2%. From 1963, and year of initial sampling through 1966, the incidence in sheep was, respectively, 4.4%, 0.5%, 7.9% and 1.8%.

The low incidence of Q fever antibody in sheep, other livestock and wild animals from the collecting area is in great contrast to those results reported from the Hopland Field Station in northern California. Here there is a recurring annual cycle in sheep and the incidence of Q fever in other livestock, wild mammals and birds is a direct result of exposure to areas utilized by sheep. Animals feeding on the same pastures as infected livestock have a higher prevalence of Q fever CF antibody than those from bordering areas. It is thought that the infection is maintained in the sheep with large numbers of rickettsiae being shed at lambing. Such a cycle apparently does not exist in our study area as at no time has the incidence rate of CF antibody in sheep from our area risen above 8% as compared to 55% at the Hopland Field Station. The incidence of antibody in other livestock, birds, and wildlife from the Hopland Station is also higher than any found in our study area.

Rickettsia rickettsii (Rocky Mountain Spotted Fever)

A summary of the 1971 evidence of R. rickettsii activity as indicated by serological reactors in the CF test to soluble group antigen is given in Table 29. Additional summaries comparing species incidence rates for the years 1967 through 1971, animal grouping incidence rates, geographic distribution of positive specimens and livestock incidence will be found in Tables 30 to 33.

Serological reactors consisted of 270 jack rabbits, 15 rodents of four species, three cottontails and one cattle sample. No isolates were made from tissues or ectoparasites, nor did these specimens upon injection into indicator guinea pigs induce antibody formation.

It should be noted that, on the basis of many years investigation, we feel certain that a classic virulent strain of R. rickettsii is not present in the study area but that a related organism is and it is this organism, (yet to be isolated), which is responsible for the large number of serological reactors in local lagomorph and rodent populations. Since the antigen employed is a group antigen derived from a standard virulent strain of R. rickettsii, the interpretation of serological reactors, especially since approximately 70% of same exhibit titers in the 1:16 to 1:32 "borderline" range, is not clear. With this uncertainty, the various analyses and correlations that are made between reactors and ecological variables must be viewed with some reservation.

Of the 3,186 local rodents tested during 1971, 15 were reactors including 11 P. maniculatus, two D. ordii and one each A. leucurus and P. parvus. The trends in annual incidence rates among the major rodent species and among locally collected jack rabbits may be observed by reference to Figure 2 . Incidence rates were reduced from 1971 findings in all four of these species. The 0.6% rate of reactors among 162 A. leucurus found in 1971 is statistically significantly lower than the 5.6% rate detected among 213 tested during 1970, as is the 1.1% 1971 rate among 183 D. ordii when compared to the 4.9% 1970 rate among 326 of this species tested during 1970. Reactor rates observed in both of these species parallel trends in reactor rates among jack rabbits. The 1971 reactor rate of 0.6% among 1,732 P. maniculatus was lower, although not significantly, from the 1970 incidence of 1.4% of 1,829. No reactors were detected during 1971 among the D. microps tested but only 23 of these animals were obtained during the year. The reactor rate of 0.6% of 163 P. parvus was lower, but not significantly, than the 1.5% rate observed in 1970; 1970 was the first year evidence of activity in this species had been obtained since 1964.

In past years it was found that a disproportionate number of the reactive rodents were collected during the spring season, especially March, April, and May, and that rodents collected during midsummer exhibited a much lower degree of involvement than would be expected on the basis of random assortment. Such correlations are quite consistent with what is known regarding the annual abundance cycles of the tick vectors. The relatively small number of rodent seropositives detected

Table 29. Incidence of *Rickettsia rickettsii* (spotted fever group of organisms) in wildlife specimens of the Great Salt Lake Desert region as determined by complement fixing antibodies using a commercial soluble antigen, 1971.

Species	Host Number	Area	Titer
RODENTS			
Peromyscus maniculatus	71A 119	Dugway Valley	16
Ammospermophilus leucurus	71D 21	Camelback Mountain	32
Perognathus parvus	71E 56	East Wendover	16
Dipodomys ordii	71E 89	West Wendover	16
P. maniculatus	71E 242	Condie	16
P. maniculatus	71E 322	Iosepa	32
P. maniculatus	71E 504,508	Trout Creek	16,16
D. ordii	71F 7	Camelback Mountain	32
P. maniculatus	71I 273	Deep Creek	16
P. maniculatus	71J 60,74	Government Creek	16,32
P. maniculatus	71K 113	Lakeside	64
P. maniculatus	71K 203	Benmore	32
P. maniculatus	71L 19	Big Davis Mountain	16
LAGOMORPHS			
Lepus californicus	71A 24,34	Big Davis Mountain	128,64
	71A 51,52,55,56,58	Dugway Mountain	16,32,16,16,32
	71A 62	Erickson Pass	16
	71A 63	Condie	16
	71A 187	Twin Falls	64
	71A 208,210,216,218,219, 221,223,225,228,230, 231,232,233,240,242, 249,250,251,252,254, 255,256	Big Davis Mountain	32,256,256,16,64, 64,64,128,64,32, 64,64,64,32,32, 128,128,32,16,16, 16,64
	71B 90,93,94	Fish Springs	16,16,16
	71B 271	Camelback Mountain	64
	71B 284	Iosepa	32
	71B 287	West Cedar Mountain	16
	71B 295	Lakeside	16
	71B 306,325	Twin Falls	16,16
	71B 420	Big Davis Mountain	16
	71B 421,431,435,436,442	Twin Falls	32,64,64,128,64
	71B 447,449,452,453,454, 456,457,461,463,464	Big Davis Mountain	64,32,16,32,16, 32,16,16,16,16
	71C 7,9	South Cedar Mountain	64,32
	71C 15	Wig Mountain	32
Sylvilagus audubonii	71C 72	Big Davis Mountain	32
L. californicus	71C 73,75,76,77,78	Big Davis Mountain	16,64,16,16,32
	71C 282,283,285,287,288	Callao	16,32,16,64,128
	71C 291,293	Gold Hill	16,16
	71C 401,402,403,406,408, 409,410	Big Davis Mountain	16,256,64,64,128, 256,512
	71D 3,5	Condie	64,64
	71D 105,106,107	Camelback Mountain	64,64,256
	71D 108,109,112	Dugway Valley	32,32,64
	71D 113,116,117	Wig Mountain	16,16,64
	71D 181,182	Benmore	16,32
	71D 246,247,248,249,250	Dugway Mountain	64,32,32,32,32
	71D 341,342,345	West Cedar Mountain	64,32,16
	71D 346,347,348,349,350	Iosepa	16,32,16,64,16
	71D 356,363,370	Twin Falls	16,16,64
	71E 164,166,167,169,170, 171	North Wendover	32,16,32,32,16 16
	71E 172,173,174,175,178	East Wendover	128,16,16,32,32
	71E 180,181,182,184,185, 187,187	West Wendover	16,16,32,32,16, 16,16
	71E 188,190,191,192,193, 194,195	South Wendover	16,64,64,256,128, 32,32
	71E 272,274,275,276,277, 281,282	Granite Mountain	16,16,64,16,32, 32,64
	71E 331	Old Lincoln Highway	32

Table 29. Incidence of *Rickettsia rickettsii* page 2

Species	Host Number	Area	Titer
LAGOMORPHS (continued)			
... californicus	71E 550,552,557	Deep Creek	32,16,32
	71E 561,562,563,564,565	Callao	32,32,16,32,16
	71E 569,571	Gold Hill	16,16
	71E 574,576,579	Trout Creek	64,16,32
	71E 589,597,600,601,604	Twin Falls	32,64,64,64,32
	71F 1,92,94	Stansbury	64,256,128
	71F 65,66,69	Dugway Valley	64,64,64
	71F 70,71,72,73	Camelback Mountain	32,32,16,32
	71F 177,178	Erickson Pass	64,64
	71F 245	Fish Springs	32
	71F 248,249	Dugway Mountain	16,32
	71F 284,293,306	Twin Falls	16,32,64
	71G 18	Government Creek	64
	71G 20,23,25,26,27, 28,48,67,68	Stansbury	16,64,16,64,64, 256,32,256,32
S. audubonii	71G 287,288	Delta	128,32
L. californicus	71G 299	Twin Falls	64
	71H 3,5	West Cedar Mountain	32,16
	71H 37	Camelback Mountain	32
	71H 69	Government Creek	16
	71H 74,76,79	Old Lincoln Highway	32,32,16
	71H 96	Delta	32
	71H 108,109	Dugway Valley	64,32
	71H 110,113,114	Wig Mountain	32,16,16
	71H 119,122,123,124	Granite Mountain	64,32,32,16
	71H 175	Gold Hill	32
	71H 231,235	Deep Creek	32,32
	71H 287,279,288,289	Twin Falls	32,64,16,16,
	71I 631,632	West Wendover	16,16
	71I 642,644,646	North Wendover	32,32,64
	71I 647,648,649,650,651, 652,653,654	South Wendover	32,16,64,64,64, 64,16,16
	71I 667	Twin Falls	32
	71J 695,696	Big Davis Mountain	32,64
	71J 90,91	Government Creek	32,16
	71J 221,223	Camelback Mountain	16,32
	71J 233,237	Wig Mountain	16,32
	71J 240,241	Condie	512,16
	71J 243,245	Dugway Mountain	16,16
	71J 253,256,257	Fish Springs	32,16,16
	71J 267,270,271	West Cedar Mountain	16,16,32
	71J 277	Government Creek	32
	71K 5	Fenmore	32
	71K 15, 16,17,18,19, 20,22,23,25,27	Big Davis Mountain	32,64,16,64,32, 32,128,32,32,256
	71K 91	Delta	32
	71K 177,180	Old Lincoln Highway	32,16
	71K 270,279,285	Twin Falls	256,64,64
	71L 189,190	Twin Falls	64,16
	71J 367,368,378,381, 382,390	Twin Falls	128 16,16,64 64,64

Table 30. Incidence of *Rickettsia rickettsii* in wildlife specimens of the Great Basin region as determined by specific complement fixing antibodies 1967-1971.

Species	1967 Positive/Total	%	1968 Positive/Total	%	1969 Positive/Total	%	1970 Positive/Total	%	1971 Positive/Total	%
RODENTS										
Eutamias minimus	0/133	-	0/143	-	0/126	-	2/176	1.1	0/176	-
Ammospermophilus leucurus	7/430	1.6	2/157	1.3	3/99	3.0	12/218	5.5	1/162	0.6
Perognathus parvus	0/40	-	0/123	-	0/74	-	1/65	1.5	1/163	0.6
P. longimembris	0/79	-	0/14	-	2/15	13.3	0/23	-	0/22	-
Dipodomys ordii	2/470	0.4	3/315	1.0	10/336	2.9	16/326	4.9	2/183	1.1
D. microps	0/153	-	1/48	2.1	0/64	-	1/85	1.2	0/23	-
Reithrodontomys megalotis	0/27	-	0/85	-	0/201	-	1/163	0.6	0/88	-
Peromyscus maniculatus	4/944	0.4	6/1568	0.4	26/1887	1.4	15/1698	0.9	11/1732	0.6
Others	0/718	-	0/774	-	0/774	-	0/675	-	0/637	-
	(22 Species)		(21 Species)		(19 Species)		(17 Species)		(14 Species)	
Total	13/2954	0.44	12/3104	0.38	41/3502	1.17	48/3406	1.40	15/3186	0.47
LAGOMORPHS										
Sylvilagus nuttallii	0/2	-	2/12	16.7	0/14	-	-	-	-	-
S. audubonii	3/23	13.0	12/31	38.7	19/63	30.2	6/17	35.3	3/75	4.0
Lepus townsendii	0/1	-	0/2	-	2/15	13.3	-	-	-	-
L. californicus	112/837	13.4	219/1294	16.9	352/1722	20.4	303/991	30.9	270/984	27.3
Others	0/3	-	0/1	-	-	-	-	-	-	-
	(1 Species)		(1 Species)							
Total	115/866	13.27	233/1340	17.38	343/1814	20.56	309/1008	30.96	273/1059	25.78
OTHER VERTEBRATES										
Vulpes macrotis	0/40	-	0/31	-	0/21	-	1/29	3.4	0/11	-
Others	0/39	-	0/54	-	0/78	-	0/61	-	0/57	-
	(8 Species)		(6 Species)		(8 Species)		(8 Species)		(6 Species)	
Total	0/79	-	0/85	-	0/99	-	1/90	-	0/68	-
AVES										
All species	0/616	-	0/544	-	0/444	-	0/19	-	0/3	-
	(26 Species)		(28 Species)		(31 Species)		(4 Species)		(3 Species)	

Table 31. Incidence of *Rickettsia rickettsii* in lagomorphs of the Great Basin region as determined by specific complement fixing antibodies 1967-1971.

Area	1967 Positive/Total	%	1968 Positive/Total	%	1969 Positive/Total	%	1970 Positive/Total	%	1971 Positive/Total	%
GROUP I										
Old Lincoln Highway	0/8	-	1/12	8.3	13/27	48.1	6/29	20.7	6/30	20.0
Wig Mountain	6/17	35.3	3/15	20.0	13/41	31.7	14/30	46.7	9/30	30.0
Camelback Mountain	3/27	11.1	10/32	31.3	13/30	43.3	14/31	45.2	11/35	36.7
Dugway Valley	3/16	18.8	3/15	20.0	17/37	45.9	15/30	50.0	8/30	26.7
Granite Mountain	0/4	-	1/15	6.7	4/17	23.5	14/25	56.0	11/27	40.7
GPI-3	0/1	-	0/1	-	-	-	-	-	-	-
Little Davis Mountain	0/13	-	1/8	12.5	-	-	-	-	-	-
Old River Bed	4/13	30.8	0/8	-	-	-	-	-	-	-
Total	16/99	16.16	19/106	17.92	60/152	39.47	63/145	43.44	45/152	29.60
GROUP II										
South Cedar Mountain	0/12	-	2/13	15.4	10/20	50.0	8/20	40.0	2/20	10.0
Government Creek	3/13	23.1	4/14	28.6	7/24	29.2	4/20	20.0	5/34	14.7
Iosepa	4/12	33.3	3/13	23.1	2/20	10.0	6/22	27.3	6/20	30.0
Condie	3/8	37.5	5/12	41.7	4/21	19.0	8/19	42.1	5/20	25.0
Big Davis Mountain	0/14	-	6/19	31.6	57/113	50.4	52/163	31.9	60/131	45.8
West Cedar Mountain	0/4	-	3/8	37.5	2/15	13.3	8/20	40.0	9/20	45.0
Total	10/63	15.87	23/79	29.11	82/213	38.49	86/264	32.57	87/245	35.51
GROUP III										
Erickson Pass	4/12	33.3	12/25	48.0	5/25	20.0	13/24	54.2	3/25	12.0
Dugway Mountain	4/12	33.3	6/16	37.5	12/23	52.2	16/24	66.7	14/24	58.3
Fish Springs	5/9	55.6	0/15	-	7/20	35.0	10/24	41.7	7/22	31.8
Gold Hill	2/11	18.2	6/16	37.5	2/31	6.5	8/20	40.0	5/40	12.5
Trout Creek	2/10	20.0	4/17	23.5	2/25	8.0	13/24	54.2	3/24	12.5
Callao	3/16	18.8	4/16	25.0	9/24	37.5	13/24	54.2	10/24	41.7
Gandy	2/17	11.8	6/16	37.5	-	-	-	-	-	-
Total	22/87	25.28	38/121	31.40	37/148	25.0	73/140	52.14	42/159	26.42
GROUP IV										
Lakeside	1/18	5.6	2/13	15.4	3/16	18.8	11/26	42.3	1/16	6.3
Stansbury	4/18	22.2	8/13	53.3	6/16	37.5	11/22	50.0	12/43	27.9
Benmore	2/8	25.0	2/14	14.3	10/16	62.5	3/16	18.8	3/16	18.8
Deep Creek	7/14	50.0	0/12	-	5/16	31.3	3/1	17.6	5/16	31.3
East Wendover	2/4	50.0	3/7	42.9	4/6	66.7	7/16	43.8	5/11	45.4
South Wendover	1/3	33.3	6/12	50.0	7/11	63.6	6/11	54.5	15/16	93.8
West Wendover	3/16	18.8	6/16	37.5	3/13	23.1	8/16	50.0	9/16	56.2
North Wendover	5/8	62.5	4/6	66.7	8/10	80.0	9/16	56.3	9/16	56.3
Delta	-	-	-	-	-	-	-	-	4/57	7.0
Wasatch Front	-	-	-	-	0/20	-	0/3	-	-	-
Total	25/89	28.08	31/93	33.33	46/124	27.09	58/143	40.55	63/207	30.43
GROUP V										
Curlew Valley	3/8	37.5	-	-	-	-	7/21	33.3	-	-
Dragerton	0/2	-	-	-	-	-	-	-	-	-
Duchesne-Roosevelt	-	-	2/4	50.0	-	-	-	-	-	-
Fillmore	-	-	-	-	0/3	-	-	-	-	-
Twin Falls	39/518	7.5	120/937	12.8	148/1174	12.6	22/295	7.7	36/299	12.0
Total	42/528	7.95	122/941	12.96	148/1177	12.57	29/316	9.47	36/299	12.04
Grand Total	155/866	13.27	233/1340	17.38	373/1814	20.56	309/1008	30.96	273/1059	25.78

Table32. Incidence of Rickettsia rickettsii complement fixing antibodies in domestic livestock sera collected in the Great Salt Lake Desert region 1967-1971.

Year	Positive 1:16 or >	Number Tested	Percent Positive	Areas yielding positive specimens
				CATTLE
1967	0	684	-	----
1968	0	73	-	----
1969	1	521	0.1	Clover
1970	0	483	-	----
1971	1	225	0.4	Grouse Creek
				SHEEP
1967	1	971	0.1	Topaz
1970	0	1225	-	----
1971	0	1684	-	----
				HORSES
1967	0	18	-	----
				SWINE
1967	0	8	-	----
				GOATS
1971	0	6	-	----

Table 33. Incidence of *Rickettsia rickettsii* in wildlife specimens of the Great Basin region as determined by specific complement fixing antibodies 1967-1971.

Year	Number Positive	Number Tested	Percent Positive	Areas yielding positive specimens
				RODENTS
1967	13	2954	0.44	Camelback Mountain, Dugway Valley, GPI-3, Old River Bed, Iosepa, Fish Springs, Callao, Lakeside, Deep Creek
1968	12	3104	0.38	Old Lincoln Highway, Camelback Mountain, Granite Mountain, Old River Bed, West Cedar Mountain, Trout Creek, Callao, West Wendover
1969	41	3502	1.17	Old Lincoln Highway, Camelback Mountain, Wig Mountain, Dugway Valley, South Cedar Mountain, Government Creek, Condie, Big Davis Mountain, Erickson Pass, Dugway Mountain, Trout Creek, Callao, Lakeside, Stansbury, East Wendover, West Wendover, Bryce Canyon
1970	48	3406	1.40	Old Lincoln Highway, Wig Mountain, Camelback Mountain, Dugway Valley, Granite Mountain, Government Creek, Condie, West Cedar Mountain, Fish Springs, Lakeside, East Wendover, North Wendover
1971	15	3186	0.47	Camelback Mountain, Dugway Valley, Government Creek, Iosepa, Condie, Big Davis Mountain, Trout Creek, Lakeside, Benmore, Deep Creek, East Wendover
				LAGOMORPHS
See Table 34				
				OTHER VERTEBRATES
1967	0	79	-	----
1968	0	85	-	----
1969	0	99	-	----
1970	1	90	1.0	Condie
1971	0	68	-	----
				AVES
1967	0	616	-	----
1968	0	544	-	----
1969	0	444	-	----
1970	0	19	-	----
1971	0	3	-	----

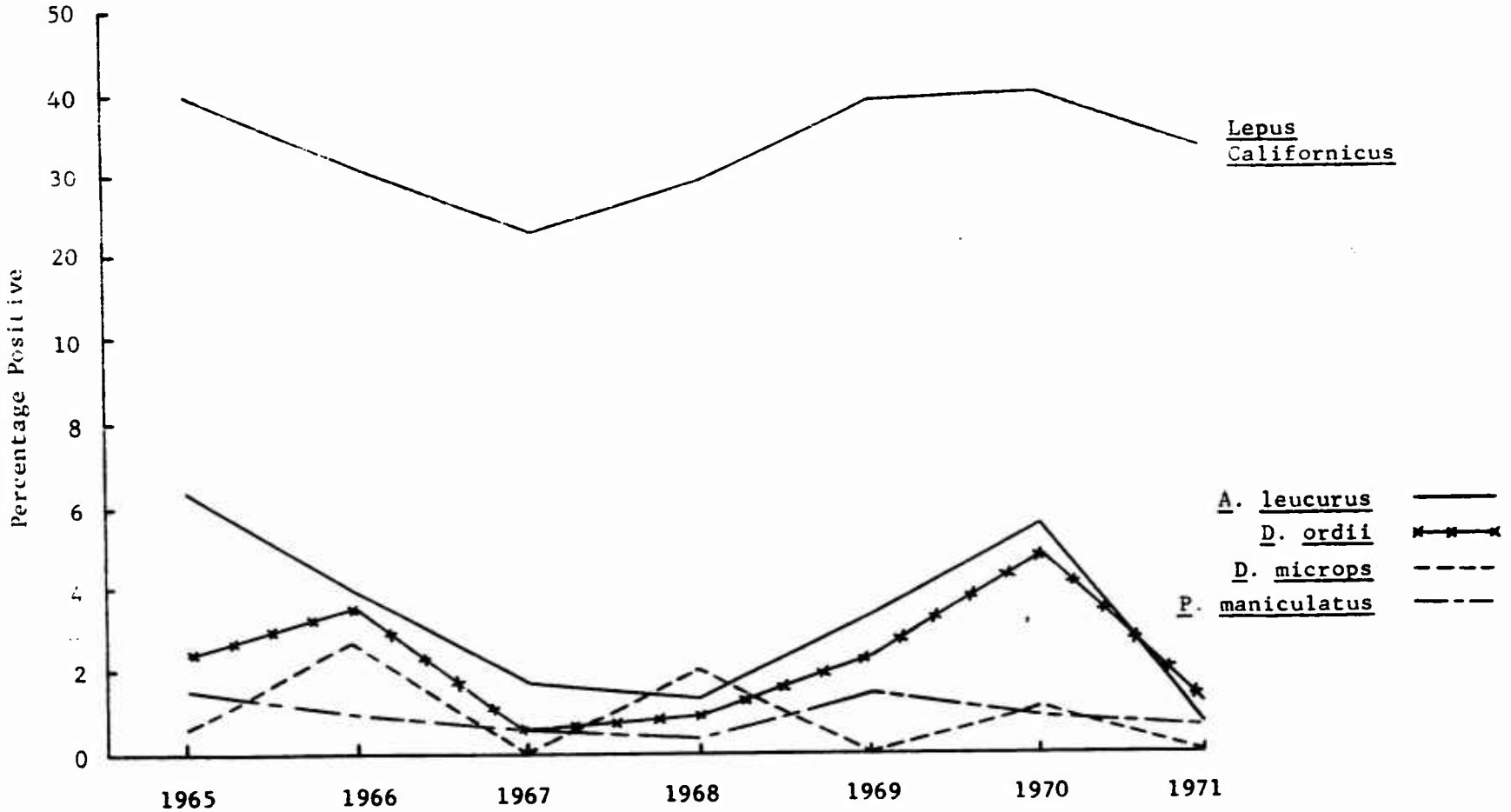


Figure 2. Variations in incidence of serological reactors to Rickettsia rickettsii antigen in key rodent species and in locally collected Lepus californicus, 1965-1971.

during 1971 made this trend less clear. Of the 15 reactors, six were collected during May while two each were collected during October and Novemeber, and one each during the months of January, April, June, September, and December. The observed May figure is significantly greater than the number expected.

Geographically, the reactive rodents were widespread with positives coming from 12 collecting areas. Only three areas, Camelback Mountain, Government Creek and Trout Creek, contributed more than one reactive rodent with each of these yielding two.

When analyzing the age structure of the population of rodent reactors in comparison with the total population sampled, the correlations vary with the species. Among deer mice, 8 of the 11 reactors were found among the three age groups most frequently sampled with four being in the 79-114 day old range, four in the 115-181 day old range and one in the 182-347 day old range. Two were older than 500 days and were among the oldest 8% of the deer mice sampled. The youngest reactive deer mouse was 85 days old. There were fewer reactors in the younger age classes than would be expected on the basis of random distribution and none in the youngest 36% of the population which includes animals up to 78 days of age. No correlation of titer with age was possible since all deer mice and other rodents had titers of 1:16 or 1:32. The only reactive A. leucurus was approximately 196 days of age and in the age group most frequently sampled. Of the two seropositive D. ordii, one was approximately 260 days of age and in the age group most frequently sampled while the other was more than 500 days of age and in the oldest 20% of the population. No reactors were detected among the youngest 40% of the sampled population which included kangaroo rats up to 256-315 days of age.

Turning to an analysis of the incidence of reactors in the jack rabbit population, the large number of same makes possible a number of correlations with age, time of collection, geographic area, etc. Locally collected jack rabbits have been aged since 1965 by the lens technique. Table34 shows the relationship of serological evidence of R. rickettsii to lens-weight age class. The general trend noted in the past of a gradually increasing incidence rate with increasing age was again evident during 1971. Peak rates are usually reached in Class 7 at age 10-14 months followed by a slight decline. The latter has been shown upon analysis of mean titer by age class to reflect animals whose titers have declined with time since exposure to the point where they are no longer classed as positive reactors; laboratory infection data indicates that reinforcement of titer does not occur in jack rabbits when re-exposed to R. rickettsii some time after initial infection. During 1971, maximum incidence rates occurred in Class 8 (14-22 months) but was not significantly different than the Class 7 or 9 rates. The 1970 picture was rather different with maximum incidence occurring in Class 6 (7-10 months) and remaining virutually constant through all succeeding age classes for which there were adequate samples.

Another analysis of the incidence of R. rickettsii seropositive jack rabbits as related to age and progression of the season is presented in Table 35 . In this analysis nearly all locally-collected jack rabbits tested were divided into two age categories, adult and young-of-the-year, by a combination of techniques and further categorized by month

Table 34. Relationship of serological evidence of Rocky Mountain spotted fever to lens weight age category in Lepus californicus, 1965-1970 and 1971.

Lens Wt. Age Category	Approx. Age in Months	1965-1970			1971		
		Number Tested	Positive Number	Positive Percent	Number Tested	Positive Number	Positive Percent
1	1- 2	53	0	0.0	12	1	8.3
2	2- 3	124	16	12.9	27	1	3.7
3	3- 4	237	54	22.8	41	5	12.2
4	4- 5	244	64	26.2	59	7	11.9
5	5- 7	353	111	31.4	51	8	15.7
6	7-10	347	118	34.0	58	10	17.2
7	10-14	386	183	47.4	116	44	37.9
8	14-22	314	142	45.2	96	44	45.8
9	22-41	228	101	44.3	82	31	37.8
10	41+	112	43	38.4	22	6	27.3
11		21	7	33.3	8	3	37.5
12		3	3	100.0	0	0	0.0
Totals		2422	842	34.8	572	160	28.0

Table 35. Correlation of Rocky Mountain spotted fever seropositives in *Lepus californicus* with age and month of collection, 1965-1970 and 1971.

		January	February	March	April	May	June	July	August	September	October	November	December	Total
Adults 1965-1970	Number Positive	51/172	56/148	86/214	64/121	136/324	49/111	36/82	20/47	43/103	52/112	24/54	4/7	621/1495
	Percent Positive	29.6	37.8	40.2	52.9	42.0	44.1	43.9	42.5	41.7	46.4	44.4	57.1	41.5
Adults 1971	Number Positive	9/61	8/30	18/55	26/50	45/78	13/19	3/13	14/24	7/9	15/28	12/20		170/377
	Percent Positive	14.7	26.7	32.7	52.0	57.7	68.4	23.1	58.3	77.8	53.6	60.0		45.1
Juveniles 1955-1970	Number Positive				0/4	17/89	23/127	13/129	24/105	60/105	53/191	46/163	10/23	246/936
	Percent Positive				0.0	19.1	18.1	10.1	22.8	57.1	27.7	28.2	43.5	26.3
Juveniles 1971	Number Positive				0/1	0/6	2/26	5/30	3/38	11/58	2/32	2/18		25/209
	Percent Positive				0.0	0.0	7.7	16.7	7.9	18.9	6.2	11.1		11.9
All Ages * 1965-1970	Number Positive	51/177	56/148	86/214	64/125	153/413	72/238	49/211	44/152	103/308	105/303	70/217	133/323	986/2829
	Percent Positive	28.8	37.8	40.2	51.2	37.0	30.2	23.2	28.9	33.4	34.6	32.2	41.1	34.8
All Ages * 1971	Number Positive	31/112	18/51	25/67	26/51	45/84	15/45	8/43	17/62	18/67	17/60	14/38		234/680
	Percent Positive	27.7	35.3	37.3	51.0	53.6	33.3	18.6	27.4	26.9	28.3	36.8		34.4

* The all age totals include those tested from the winter concentration area in Big Davis Mountain which were not aged by the eye lens technique.

of collection. The number tested and percentage positive by month for each age class for the 1965-70 period and for 1971 are shown in this compilation. The adult reactor percentage has changed significantly each year beginning at 46.4% in 1965, declining to 37.6% in 1966 and 27.9% in 1967, and then commencing an upward trend to 35.4% in 1968, 45.1% in 1969 and 54.4% in 1970. The first reversal of this trend occurred in 1971 when the adult incidence rate dropped significantly to 45.1%. The juvenile incidence rate has followed much the same trend varying by year from 1965 through 1971 at the rates of 31.0%, 21.0%, 14.6%, 23.7%, 25.7%, 25.1% to 11.9% in 1971. While juvenile incidence is significantly lower than the adult rate for any given year, the change from one year to the next was significant only from 1967 to 1968 and from 1970 to 1971. The incidence rate from the combined sample of adults and juveniles, 34.4% is also significantly lower than the 1970 equivalent figure of 40.2%.

Information regarding seasonal variation in the incidence of R. rickettsii serological reactors may also be gained from Table 35 There is some variation from year to year but the "typical" picture in adult jack rabbits is an increase during the first part of the year to a peak incidence rate in April or May followed by a summer decline and then an increase in the percentage of reactors during autumn. Incidence rates then generally fall during the winter months reaching a low in January or February. This pattern follows closely the activity of D. parumapertus and is affected, as are the ticks, by weather and other factors. The overwinter decrease typically noted in the percentage positive is most likely due to the fact that antibody levels have fallen with time since immunizing exposure to a point where they are not detected by our heterologous antigen. Juveniles are generally first sampled in late spring exhibiting a low percentage of reactors and then the reactor rate increases steadily and quite rapidly through late autumn. During some years, however, the juvenile reactor rate peaks very rapidly and shows the mid-summer depression and fall upsurge of the adult pattern. This may be correlated with production of young taking place earlier than average with the result that juveniles comprising the May and June samples are older than the juveniles comprising these samples in other years and thus would have had more opportunity to be exposed to the antibody-inducing organism.

Table 36 shows the frequency distribution of titers in the adult and juvenile age classes for the 1965-70 period and for 1971. It will be noted that approximately 70% of the positive reactors fall in the low titer range of 1:16 and 1:32. Even the highest titers, i.e., 1:128 to 1:512, comprising less than 10% of the total, are not particularly high when compared with the titers resulting from experimental infection of jack rabbits with a classic strain of R. rickettsii, thus reinforcing the opinion that the organism which induces the CF reaction is similar but not identical to R. rickettsii.

The mean titers, when analyzed by major age classes (adult vs. juvenile) on a monthly basis, also follow along well with what would be expected from that which is known about the seasonal abundance of D. parumapertus, the rabbit tick. There is a late spring increase in mean titer of adult rabbits correlated with exposure to a large number of

Table 36. Frequency distribution of Rocky Mountain spotted fever CF titers in Lepus californicus by age category during 1965-1970 and 1971.

Reciprocal of Titer	Adults Number	Adults Percent	Juveniles Number	Juveniles Percent	All Ages Number	All Ages Percent
1965-1970						
16	255	41.3	94	38.5	349	40.5
32	189	30.6	85	34.8	274	31.8
64	120	19.4	41	16.8	161	18.7
128	48	7.8	17	7.0	65	7.5
256	3	0.5	7	2.9	10	1.2
512	2	0.3	0	0.0	2	0.2
	617		244		861	
Geometric Mean Titer	31.2		32.1		31.4	
1971						
16	73	37.2	7	28.0	80	36.2
32	63	32.1	8	32.0	71	32.1
64	43	21.9	7	28.0	50	22.6
128	8	4.1	2	8.0	10	4.5
256	8	4.1	0	0.0	8	3.6
512	1	0.5	1	4.0	2	0.9
	196		25		221	
Geometric Mean Titer	33.6		39.9		34.2	

larval and nymphal ticks followed by diminishing titers in mid-summer; there is another late autumn increase in titer followed by a rather precipitous drop at the end of the year. In juvenile rabbits, the mean titer usually increases rapidly in late summer and early autumn concomitant with increased tick exposure, which, at this time of year is primarily due to adult ticks. These same trends, with minor variations, have been present in each of the years this analysis has been made.

As was shown in Table 31, jack rabbit reactors to R. rickettsii antigen were collected from all regularly sampled geographic areas. Although there are some large differences in area incidence rates, analysis has shown these reflect differences in the age composition of the sample or the time of collection rather than being any true indication of significantly greater or less activity in any given local area. Those areas which exhibited incidence rates far above the average include South Wendover (93.8% of 16), Dugway Mountain (58.3% of 24), North Wendover (56.3% of 16) and West Wendover (56.2% of 16).

Jack rabbit serum samples have been collected in the Twin Falls, Idaho region, 175 miles northwest of Dugway since 1966 by personnel of the U.S. Jack Rabbit Research Station and sent to our laboratory for disease analysis. The results of this testing, excluding one aberrant area, Aberdeen, sampled only in 1968 and 1969, showed much lower reactor rates ranging from 6.2% to 9.5% on an annual all-age basis during the time local jack rabbits exhibited incidence rates of 22.2% to 36.3%. The Idaho data did not exhibit as strong seasonal variation in incidence rates as observed locally but mean titers were generally higher.

During 1970 and 1971, the Twin Falls collection averaged 25 per month from one localized area rather than being much more widespread geographically. The overall incidence rate of reactors of 7.5% and 12.0% in 1970 and 1971 respectively, were both significantly lower than the comparative rates of 40.2% and 34.4% determined locally. However, the incidence rates observed in the Twin Falls population were not significantly different when comparing the two years. The Idaho data also showed very strong April and August peaks in 1970 separated by a very low summer rate. It was thought that the confinement of collections to the one localized area may have been instrumental in allowing this seasonal variation to be revealed whereas in prior years it was masked by natural phenological variations which occurred over the broad geographic area. The 1971 data, however, did not follow this same pattern with peaks occurring in February, May, and October. Twin Falls jack rabbits did exhibit higher titers than those collected in the regular Utah study area with the mean titer being 41.9% and 44.4% of the titers being 1:16 and 1:32 as contrasted to comparative figures of 34.2% and 68.3% for Utah jack rabbits during 1971.

IMPROVEMENT OF DIAGNOSTIC TECHNIQUES

During 1971, three major areas of improvements in diagnostic techniques were investigated and evaluated. These include; (1) the hemagglutination test for F. tularensis: (2) the passive hemagglutination test for Y. pestis; and (3) the hemolymph test for the detection of R. rickettsii or related rickettsiae in ticks. The first two of these procedures have been described in the tularemia and plague sections of this report.

The methods routinely employed for the detection of rickettsial pathogens in ticks are costly and laborious. Large numbers of ticks are pooled, triturated and injected into susceptible animals, usually guinea pigs. The pooling of the ticks results in the possibility that a single pool may contain one or several pathogens. The pathogens may be in such small numbers that dilution during trituration of the pool may result in the organisms going undetected. The hemolymph test (Burgdorfer, W., HEMOLYMPH TEST: A technique for detection of rickettsiae in ticks. Am. J. Trop. Med. Hyg. 19: 1010-1014, 1970) provides a simple technique for the detection of rickettsiae in a single tick and the treatment of the tick individually in an attempt to isolate and identify the organism.

The test consists of collecting hemolymph on a slide from the distal portion of one or more amputated tick legs. The hemolymph is heat-fixed, stained by the method of Gimenez and examined microscopically Fluorescent microscopy may also be used in the hemolymph test to provide rapid identification of the antigenic group to which the organism belongs. Ticks found to be positive in the hemolymph test can be subjected to a second bleeding for fluorecent microscopical studies for identification of the antigenic group to which the rickettsial agent belongs. For this purpose the smears are air-dried, fixed in acetone and then treated with fluorescein isothiocyanate-labeled antisera.

Ticks may harbor bacteria, however, these may easily be differentiated from rickettsiae by their morphology and staining properties.

The procedure used for obtaining hemolymph does not damage the ticks and live specimens may be maintained in the laboratory until testing thus preventing loss of fragile organisms due to freezing and thawing. The system also has the advantage of the possible mating of infected females to produce transovarially infected progeny for further study.

A limited amount of hemolymph testing was conducted during late 1971 primarily to perfect methodology. In the spring of 1972 routine collecting of ticks, primarily D. parumapertus from jack rabbits, was begun for testing by this method. The hemolymph test holds much promise as a necessary step in the eventual isolation of the R. rickettsii-like organism responsible for the large number of serological reactors in the CF test for R. rickettsii.

ECOLOGICAL INVESTIGATIONS OF THE NATIVE FAUNA

Jack Rabbit Ecology and Population Dynamics

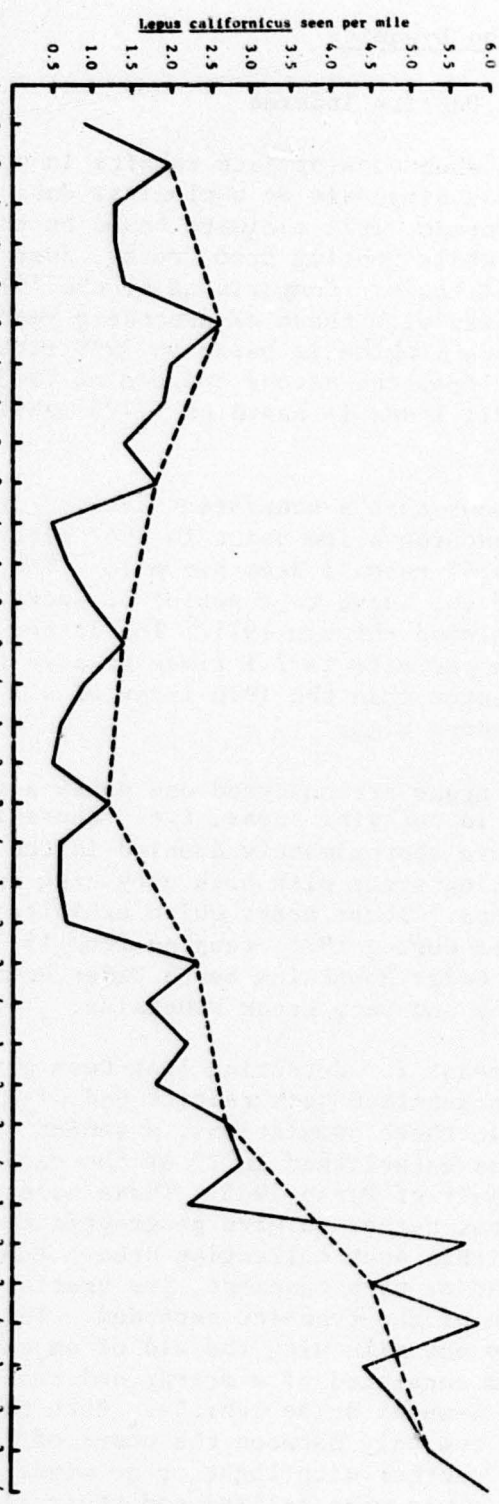
Population Fluctuations and Density Indexes

An estimate of the relative abundance of jack rabbits in populations sampled either for disease diagnosis or biological data has been made since 1963. Although crude, this estimate based on the number of rabbits seen per mile while hunting from trucks, does allow comparisons to be made on several bases. Comparisons of the 1971 quarterly and annual rabbit indexes with those of preceding years can be made by reference to Figure 3 which is based on 9,958 rabbits sighted in 6,085 miles of driving from the second quarter of 1963 through the end of 1971. The 1971 index is based on 1,773 rabbits seen in 353 miles of driving.

Reference to this Figure shows that a consistent decline in populations commenced in 1964 reaching a low point in 1967 with that year's annual index being only 0.67 rabbits seen per mile. The year 1968 marked the first upswing of the curve to a period of increasing populations; this trend has continued through 1971. The latter year's annual index of 5.0 rabbits seen per mile is 7.1 times greater than the 1967 index and 1.2 times greater than the 1970 index of 4.2 per mile, the previously recorded record high.

When individual collecting areas are analyzed one notes a general trend toward higher populations in outlying areas, i.e., those in Groups III and IV, where the indexes have approximately doubled in the past two years, but there are collecting areas with both very high and very low indexes within all area groups. Those areas which exhibited the highest annual population indexes during 1971, ranging from 15-25 rabbits per mile, included West Cedar Mountains, South Cedar Mountains, Camelback Mountain, Dugway Valley and Deep Creek Mountains.

In an effort to develop a means for detecting long-term population changes and cycles in black-tailed jack rabbits and also determine the seasonal changes in these populations, a series of 119 mile-long permanent transects was established in 27 of the regular collecting areas in the latter half of March 1965. These were selected, not on a random basis, but rather to give geographic coverage in the typical rabbit habitat within each collecting area. A marker was erected at the starting point of each transect, its precise location defined and the azimuth of the transect recorded. This azimuth was followed for exactly one mile with the aid of an automobile compass. The survey team consisted of a driver and two observers in the rear of 3/4 ton, 4-wheel drive vehicle. Both the March and August transects were run only between the hours of 10:00 a.m. and 4:00 p.m. during sunny weather with light or no wind. All rabbits sighted on the one-mile strip were tallied and their flushing distance estimated and recorded. Additional data were recorded regarding the time of day, weather conditions, type and quality of habitat, etc.



Miles Driven	Rabbits Seen	Rabbits Seen/Mile	Annual Avg. Seen/Mile
302	272	0.9	
146	287	2.0	1.2
79	100	1.3	
44	59	1.3	
143	197	1.4	
96	249	2.6	1.7
106	184	2.0	
55	106	1.9	
223	309	1.4	
148	261	1.8	1.2
206	108	0.5	
368	246	0.7	
287	286	1.0	
89	122	1.4	0.9
268	241	0.9	
321	197	0.6	
306	144	0.5	
180	210	1.2	0.7
274	164	0.6	
309	189	0.6	
301	220	0.7	
131	304	2.3	1.1
165	265	1.7	
207	459	2.2	
295	541	1.8	
186	398	2.7	2.3
122	472	2.9	
137	302	2.2	
98	562	5.7	
73	324	4.5	4.2
69	407	5.9	
104	453	4.4	
95	463	4.9	
81	418	5.2	5.0
73	439	6.0	

Figure 3. Fluctuations in populations of Lepus californicus as revealed by the number seen per mile while hunting, by quarter, 1963-1971.

The March census is timed to provide an index of the population which has survived the winter and has entered the breeding season. The transects are re-run in August, the results of this count assumed to reflect the population increment added by productivity. At this time populations will be near maximum since breeding will have terminated and the young will have grown to a size where they can be readily counted.

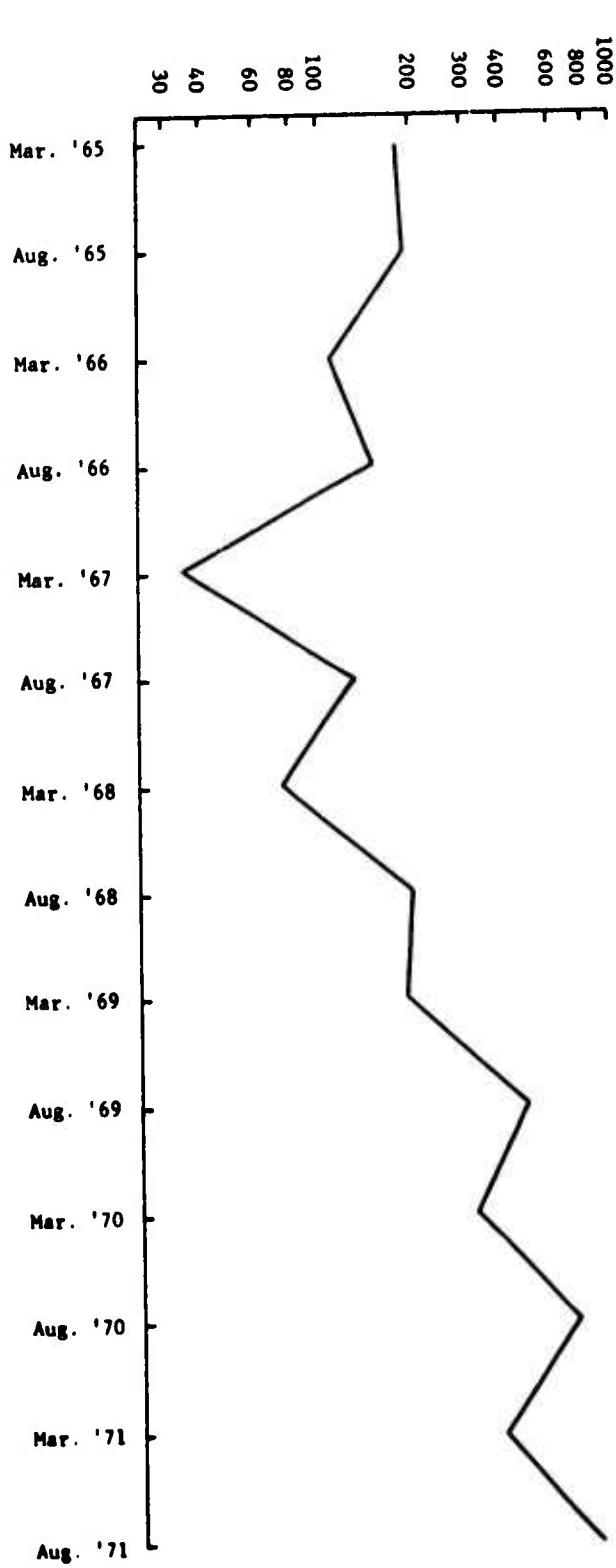
Comparing the March indexes, Figure 4, will show that the number of rabbits seen has increased steadily since the low of 35 in 1967 to 422 in 1971; the 1971 March index was 1.2 times (24%) higher than the March 1970 figure. The August indexes followed the same general trend increasing from 129 seen in 1967 to 942 in 1971, the latter figure being 1.2 times (19%) higher than observed during the preceding August. The March to August increase during 1971 was by a factor of 2.23 times (123%), this being somewhat lower than 2.3 times (133%) increase observed during the preceding year, and the 2.6 times (162%) the two years prior to 1970. Over-wintering loss, as indicated by the percentage decrease from the August to the following March indexes, was 43% during the winter of 1970-71; this was considerably higher than the 31% loss noted the preceding winter.

Breeding Biology and Population Dynamics

The year 1971 was the eighth year of an intensified effort to learn more of the basic ecology of the black-tailed jack rabbit in an attempt to elucidate the part this lagomorph plays in the epizootiology of several diseases. Methods and techniques as well as results have been detailed in previous Ecology and Epizoology Research Annual Reports. The information presented for 1971 is based on the examination of 780 jack rabbits collected during the year.

Some of the resulting data regarding breeding condition indicators in adult rabbits is shown in Table 37. Monthly testes weights of 192 adult males exhibited a pattern consistent with the previous 3 years. The mid- and late-season monthly pregnancy percentages follow the same general pattern as previous years. The January pregnancy percentage, however, of only 2.8% is much lower than the 71.9% observed in 1970 and indicates that little or no breeding took place in late December as it usually does. It does not appear that weather conditions were involved in the delay.

Additional data comparing the 1971 breeding season with those of the seven previous years is summarized in Table 38. The length of the breeding season, based on the back-dated times of conception of the average earliest and average latest adult pregnancies was approximately 10 days shorter in duration than in the two previous years but well within the extremes noted during the previous seven years of study. Both the average number of litters per female and the average litter size had decreased slightly from the two previous years and resulted in an average of 8.27 young as the seasonal production per female. The 1970 value for this figure was 9.14 young and the 1969 value was 9.02.



	Rabbit Seen	Seen/ Mile
Mar. '65	182	1.53
Aug. '65	193	1.62
Mar. '66	111	0.93
Aug. '66	152	1.28
Mar. '67	35	0.29
Aug. '67	129	1.09
Mar. '68	77	0.65
Aug. '68	201	1.69
Mar. '69	189	1.59
Aug. '69	496	4.17
Mar. '70	339	2.87
Aug. '70	791	6.70
Mar. '71	422	3.58
Aug. '71	942	7.98

Figure 4. Abundance of Lepus californicus in west-central Utah as indicated by the number seen on 119 mile-long flush transects run during March and August 1965 to 1971.

Table 37. Reproductive status of adult Lepus californicus collected during the breeding season, 1964-1971.

ADULT MALES

	Sample Size								Testes Weight Grams							
	1964	1965	1966	1967	1968	1969	1970	1971	1964	1965	1966	1967	1968	1969	1970	1971
January	14	11	35	32	17	26	26	39	9.0	6.8	9.0	5.9	8.2	8.5	8.6	7.1
February	6	15	24	15	11	36	30	15	9.6	9.2	10.7	8.6	10.1	10.6	10.4	9.3
March	4	25	11	26	11	27	33	39	10.6	10.2	11.5	9.3	10.8	10.5	10.0	10.5
April	33	34	42	4	16	6	19	35	10.8	9.1	10.8	8.5	12.1	12.1	10.9	10.9
May	37	44	18	19	18	20	21	50	9.4	8.1	4.5	9.6	9.9	8.6	8.6	9.3
June	5	4	6	10	11	6	22	8	8.8	1.0	1.0	8.1	5.0	5.0	4.0	5.5
July	12	14	3	9	5	6	6	6	4.2	1.6	<1.0	4.8	1.0	<1.0	1.6	1.7

ADULT FEMALES

	Sample Size								Percent Pregnant								Embryos per Pregnant Female							
	'64	'65	'66	'67	'68	'69	'70	'71	'64	'65	'66	'67	'68	'69	'70	'71	'64	'65	'66	'67	'68	'69	'70	'71
January	6	12	44	15	12	24	32	36	16.7	0.0	36.4	20.0	0.0	58.3	71.9	2.8	1.0	0.0	1.2	2.0	0.0	1.7	1.2	2.0
February	4	16	25	10	12	28	22	29	75.0	82.9	64.0	80.0	91.7	75.0	68.2	86.2	1.3	2.0	1.6	1.5	1.1	2.1	2.8	2.2
March	4	25	13	18	34	25	21	36	75.0	68.0	76.9	88.9	64.8	88.0	95.2	86.1	3.7	3.2	3.6	2.5	4.9	5.0	4.4	4.1
April	22	26	139	2	19	20	26	25	59.1	55.5	79.1	100.0	84.2	75.0	80.8	76.0	5.1	3.4	5.3	4.5	5.7	6.4	5.7	4.9
May	40	27	31	19	37	21	21	47	90.0	59.2	38.7	95.0	93.9	85.7	66.7	75.0	4.5	3.9	4.4	5.0	5.2	4.7	3.7	4.4
June	1	11	10	25	11	21	20	17	100.0	45.4	0.0	92.0	18.2	9.5	50.0	52.9	4.0	1.8	0.0	3.8	3.5	4.5	3.4	3.7
July	11	27	10	7	4	18	10	7	27.3	14.8	0.0	14.3	0.0	5.6	0.0	0.0	4.0	2.2	0.0	3.0	0.0	1.0	0.0	0.0

Table 38. Comparisons of Lepus californicus reproductive data, 1964-1971.

	1964	1965	1966	1967	1968	1969	1970	1971
Onset of breeding	Jan. 7	Jan.8	Dec. 28	Jan. 16	Jan. 5	Dec. 30	Dec. 23	Jan. 7
Termination of breeding	June 23	June 25	May 24	June 17	May 4	May 23	May 15	May 21
Length of breeding season, in days	168	168	147	151	120	144	143	134
Average interval between litters, in days	57.6	61.5	59.2	54.0	55.6	58.7	54.8	55.9
Average number of litters per female	2.91	2.73	2.48	2.79	2.16	2.45	2.61	2.40
Average size of litters half-term or older	3.94	2.07	4.41	3.96	4.21	3.67	4.04	3.48
Average size of litters half-term or older, corrected for seasonal variation	3.67	2.48	3.53	3.37	3.80	3.68	3.50	3.45
Total breeding season production of young per female	10.68	6.77	8.75	9.39	8.21	9.02	9.14	8.27
Percentage young-of-the-year in collections from July-December	62.0	55.3	68.4	70.2	75.8	72.2	63.5	66.3
Adult: Young-of-the-year ratios in collections from July-December	1:1.64	1:1.24	1:2.17	1:2.36	1:3.13	1:2.60	1:1.74	1:1.98

Intrauterine mortality was little changed from the two previous years. Pre-implantational loss, as determined by comparison of the number of corpora lutea with the number of embryos in pregnant females, was 4.2% with 474 corpora lutea associated with 454 embryos. Previous losses from 1970 through 1964 were, in order, 6.8%, 7.0%, 5.8%, 11.2%, 9.9%, 25.1% and 18.1%. Post-implantational loss, as determined by embryo resorption rates, was low with 9.2% of the total litters and 3.9% of all embryos examined being affected. These figures are similar to those observed since 1967 and are much lower than during 1966 when resorption was observed in 24.4% of all litters involving 22.0% of the embryos examined.

From May through December, 1971 of 110 young-of-the-year females, lens age category 3 or older, 4 or 3.6% exhibited evidence in the form of corpora lutea, enlarged reproductive tracts or embryos that they had bred. The incidence of juvenile breeding has been quite variable over the last several years with the annual figures ranging from 23.1% in 1967, declining to 8.5% in 1968 and to 0.7% in 1969, then rebounding to 9.8% in 1970. In some years, then, juvenile breeding could add a significant increment to the annual production. Such did not seem to be the case in 1971.

All jack rabbits collected during the year were aged by the eye lens weight technique; the frequency distribution of the lens weights from 761 animals collected during 1971 may be compared with that of 3,562 animals collected during the 1965-70 period by reference to Table 39 and Figure 5 . Analysis of the 1970 and 1971 distributions when compared with each of the individual distributions for previous years has shown that there was a definite slowing of the rate of population expansion as witnessed by the shift away from the great predominance of younger age classes in the collection. In 1966, when populations were still declining, the percentage of rabbits in the collection less than one year of age was 58.1% while in 1967, when populations reached record lows in the spring and commenced an upturn in the fall, this percentage rose to 68.6%. As the greatest rate of growth occurred during 1968 and 1969, juveniles comprised 73.2% and 72.2% of the collection. Although the population still increased during 1970, the rate of increase was considerably lower and this was reflected in, among other parameters, the proportion of those less than a year old with this figure decreasing to 65.7%. In 1971, this proportion declined further to 62.2%.

Utilizing all available age criteria, it was found that from July through December, 1971, when the majority of young were as susceptible to collecting as adults, 66.3% of 366 rabbits collected were young-of-the-year. The comparative percentages found during 1964-70 respectively were, 62.0%, 55.3%, 68.4%, 70.2%, 75.8%, 72.2% and 63.5%. The similarity of the 1970 and 1971 figures suggests that the population growth rate, while lower than the two previous years, had temporarily stabilized.

A crude estimate of young-of-the-year mortality may be gained by comparison of the ratio of adult to young rabbits in the collection from July through December with that ratio expected if no

Table 39. Frequency distributions of dried lens weights of Lepus californicus collected, 1965-1971.

Lens Weight Category	Lens Weight in mg.	Approximate Age Days	Approximate Age Month	1965-1970 Number of Individuals	1965-1970 Percentage	1965-1970 Cumulative Percentage	1971 Number of Individuals	1971 Percentage
1	60- 85	34- 55	1- 2	65	1.8	1.8	14	1.8
2	86-110	56- 81	2- 3	151	4.2	6.0	32	4.2
3	111-135	82- 113	3- 4	231	6.5	12.5	52	6.8
4	136-160	114- 153	4- 5	332	9.3	21.8	64	8.4
5	161-185	154- 208	5- 7	388	10.9	32.7	75	9.8
6	186-210	209- 288	7- 9	523	14.7	47.4	94	12.3
7	211-235	289- 414	9-14	678	19.0	66.4	144	18.9
8	236-260	415- 649	14-21	579	16.2	82.6	122	16.0
9	261-285	650-1243	21-41	429	12.0	94.6	112	14.7
10	286-310	1244+	41+	167	4.7	99.3	41	5.4
11	311-335			15	0.4	99.8	11	1.4
12	336-360			4	0.1	100.0		
	Totals			3562			761	

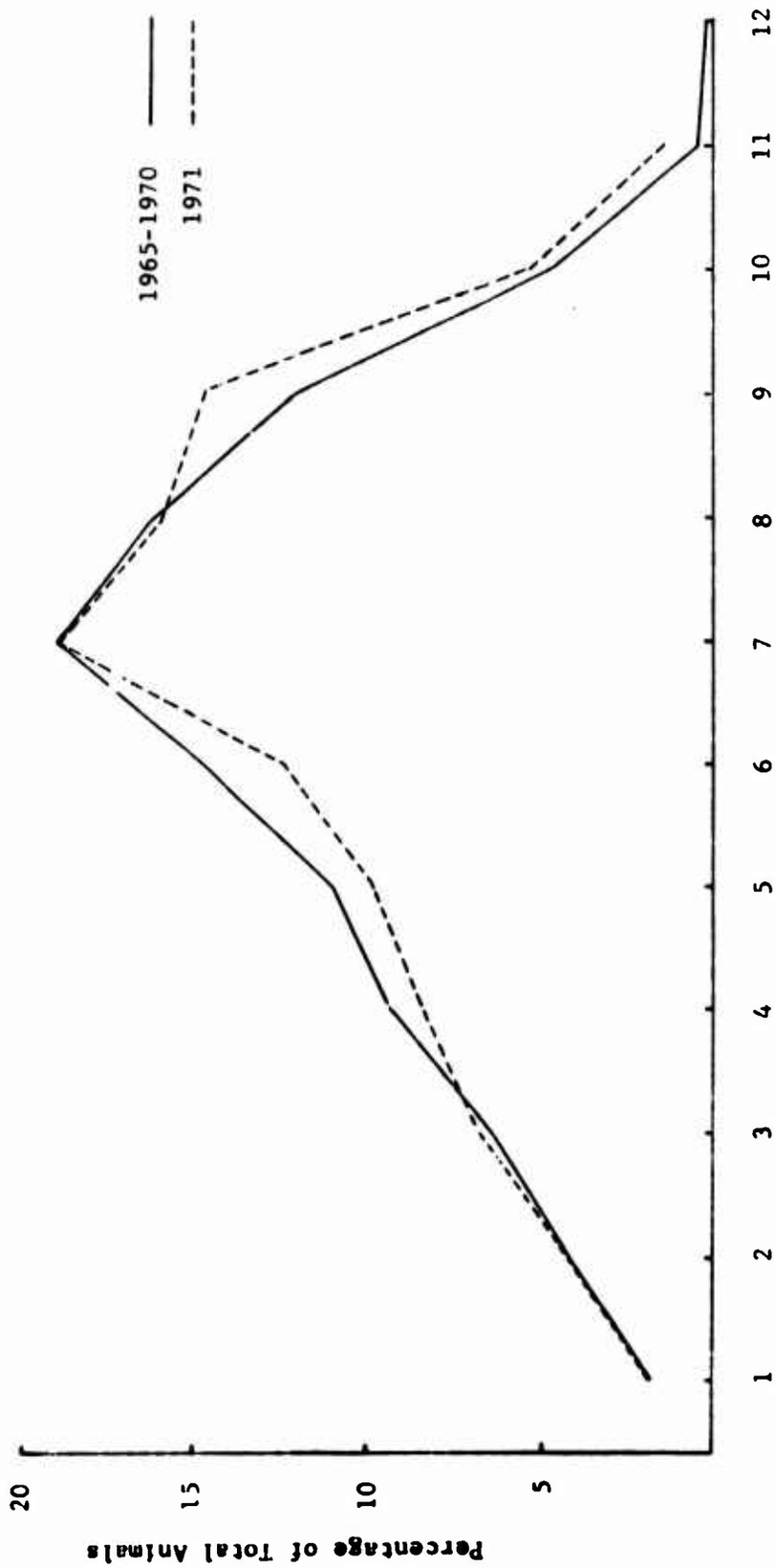


Figure 2. Frequency distributions of dried lens weights of Lepus californicus sampled from the wild, 1965-1971.

mortality had taken place, i.e., if all of the calculated 7.97 young produced per female survived. This comparison rests on the assumptions that adults and juveniles are collected in the same proportion as their actual occurrence in the population, that each female did in fact give birth to an average of 7.97 young and that there was no adult mortality from the beginning of the breeding season. The last-named assumption is known to be false with data suggesting that mortality of adults is often in the range of 25-50% from early spring to late fall, but the error introduced would tend to indicate a higher survival of young than was the case; error in the other two assumptions would probably be in the direction of indicating a lower survival than occurred in fact. In spite of these shortcomings, when the same method is applied to the data each year, definite valid trends emerge which correlate well with other objective and subjective information. The observed ratio of adults to young was 1:1.98, whereas the maximum theoretical ratio would be 1:3.98, thus indicating a survival of only 49.7% of the breeding season production. Comparative data for the years 1964-70 respectively show survival rates of 30.7%, 36.7%, 49.6%, 50.3%, 76.3%, 56.9% and 38.1%. The considerably greater survival rate experienced in 1971 as compared to 1970 was apparently offset by the lower production per female and resulted only in a modest population growth on a par with that noted in the previous year.

A number of detailed demographic analyses are made of the rabbit population each year employing the life table concept and utilizing a number of factors such as age ratios at various times of the year, productivity data, population changes as reflected in transect counts, etc. These are generally too lengthy to be included in the Annual Summary Reviews, but the findings form the basis for conclusions expressed here. Of the factors which have emerged from these analyses as being quite variable and influential, the juvenile survival rate seems to be of prime importance and appears much more influential than natality in determining the fate of the population. Tremendous changes in juvenile loss, especially from late summer to the beginning of the next breeding season ranging from 81% over this period in 1966-67, through 37% the next year, to a low of 9% in 1968-69, up to 40% in 1969-70 and increasing further to 53% in 1970-71, seem to be the primary proximate factors involved in the increasing rabbit population noted. It can readily be shown that with the annual production rates which have prevailed for the last six years, a loss of 80-82% of the entire population, adults and young combined, can occur during the one year period from the beginning of one breeding season to the next and still have the population remain at the same level. Even if no adults survive to the next breeding season, a 75-79% loss of the year's total production will be tolerated and result in a stable population. Analysis has shown that during the period from March 1967 to March 1968 about 61%, from March 1968 to March 1969 about 52%, and from March 1969 to March 1970 about 67%, and from March 1970 to March 1971 about 78% of the total population died. During these same periods, 68%, 54%, 73%, and 83% respectively of the production of young was lost. Thus, in spite of these apparently high mortality rates, the 15-25% margin over the population equilibration point has allowed the rabbit populations to increase very substantially over the past several years. However, with this margin narrowing to 2-10% during 1970

and 1971 the rate of increase has accordingly been much depressed.

While the probability that an individual new-born rabbit will survive to its first or second birthday are exceedingly slim, on the order of .15, population analysis has shown that those which do survive the hazards of the first summer, fall and winter have a much higher probability of surviving longer; even this probability is not great as is witnessed by returns of rabbits trapped, marked and released as part of the winter rabbit concentration area study noted in the next section of this report. Of 306 rabbits, 8 months of age or older, marked and released during two consecutive winters, only 25 or 8.2% were sighted or recaptured the following winter. A portion of this group, 115 animals, was theoretically available during the third winter of study, two years from their initial tagging, when all would have been at least 32 months of age; only 5 or 4.3% were recaptured at that time. A slight but insignificant higher return of males than females has been obtained in this study. These recapture percentages are probably considerably lower than the true survivorship of the older animals in the population since there are a number of factors, largely weather-related, which dictate what proportion of animals in the concentration area one winter will return and be available for recapture during succeeding winters. Additional work in this area combined with age analysis of the population in general will further refine the figures, since they are at variance with other analyses which indicate a probability of .45-.60 that an adult will survive from its first breeding season to the next.

Rodent Ecology and Population Dynamics

Population Fluctuations and Density Indexes

The trap-night index, in spite of its many shortcomings, has been used since 1963 to obtain estimates of the relative abundance of rodents. The standardized trapping methods and time scheduling of trapping varying little from year to year, and the adjustment of trap-nights available for those traps sprung by wind, rain, malfunctioning traps and diurnal animals, combined with the large sample sizes involved are all thought to combine to make the trap-night indexes more reliable and provide information regarding the general trends of rodent population fluctuation.

During 1971, on the basis of more than 34,000 trap-nights and more than 3,623 captures, trapping efforts produced one rodent in 9.4 trap-nights or 10.6% trapping success. Geographically, trapping in Group I and II areas was least successful averaging 9.8% success on an annual basis, while success in Group III and IV areas rose to 13.8%. Individual collecting areas varied greatly in trapping success with Benmore, Erickson Pass, and Lakeside among those with the highest success rates and Iosepa, West Cedar Mountains, Government Creek, Fish Springs, Dugway Valley and Granite Mountain among those with the lowest trapping success. Various factors including frequency and timing of collections affect the annual indexes for individual collection areas.

Comparisons of relative rodent abundance on an annual and quarterly basis for the year 1963-71 may be made by reference to Table 40 and Figure 6 , both of which are based on 37,998 rodents captured in 278,167 trap-nights. Following the low trapping success of 1967, population density indicators rose sharply in 1968, and continued at the high level through much of 1969. The 1970 and 1971 indicators were at a much lower level. While populations were undoubtedly lower during 1970 and 1971, the magnitude of the decrease may not be reliable. It will be noted that the quarterly fluctuations in trapping success were not nearly of the magnitude as in most years prior to 1970. This may be due to the fact that much more trapping has been conducted in the first quarter of the year, when populations are characteristically lower, since 1970 than was done prior to that time. This would tend to depress the annual trapping success figure. Also, trapping is now done with more attention being paid to the phase of the moon with the dark phases being favored since the trend is to increase capture success and thus expend fewer man-hours to obtain the required number of rodents.

Biotic Community Relationships

The fact that certain species of rodents tend to be found only in certain biotic communities, whereas others are quite ubiquitous, and that although a species may be found in several communities it is more frequently encountered in one than in others, is well-known.

Table 40. Rodent population changes as revealed by density indexes by quarter, 1963-1971.

Year	Quarter	Trap-Nights Per Rodent	Trapping Success Percent	Annual Average Trap-Nights Per Rodent	Annual Average Trapping Success
1963	1	11.8	8.5	5.5	18.0
	2	4.0	25.0		
	3	4.1	24.2		
	4	9.3	10.8		
1964	1	12.1	8.2	7.9	12.7
	2	6.8	14.5		
	3	7.2	13.8		
	4	7.7	13.0		
1965	1	13.0	7.7	7.7	12.9
	2	6.0	16.6		
	3	5.5	18.2		
	4	11.4	8.8		
1966	1	13.5	7.4	6.2	16.2
	2	4.5	22.4		
	3	5.4	18.5		
	4	5.1	19.8		
1967	1	14.4	6.8	14.3	7.0
	2	15.0	6.6		
	3	13.7	7.3		
	4	14.0	7.1		
1968	1	7.6	13.1	4.8	20.9
	2	4.4	22.5		
	3	3.6	27.9		
	4	4.8	21.0		
1969	1	5.4	18.6	5.0	19.9
	2	4.0	25.1		
	3	5.1	19.6		
	4	7.1	14.2		
1970	1	8.8	11.3	7.9	12.6
	2	6.9	14.4		
	3	6.9	14.5		
	4	9.7	10.3		
1971	1	11.6	8.6	9.4	10.6
	2	9.0	11.1		
	3	9.6	10.4		
	4	6.9	14.4		

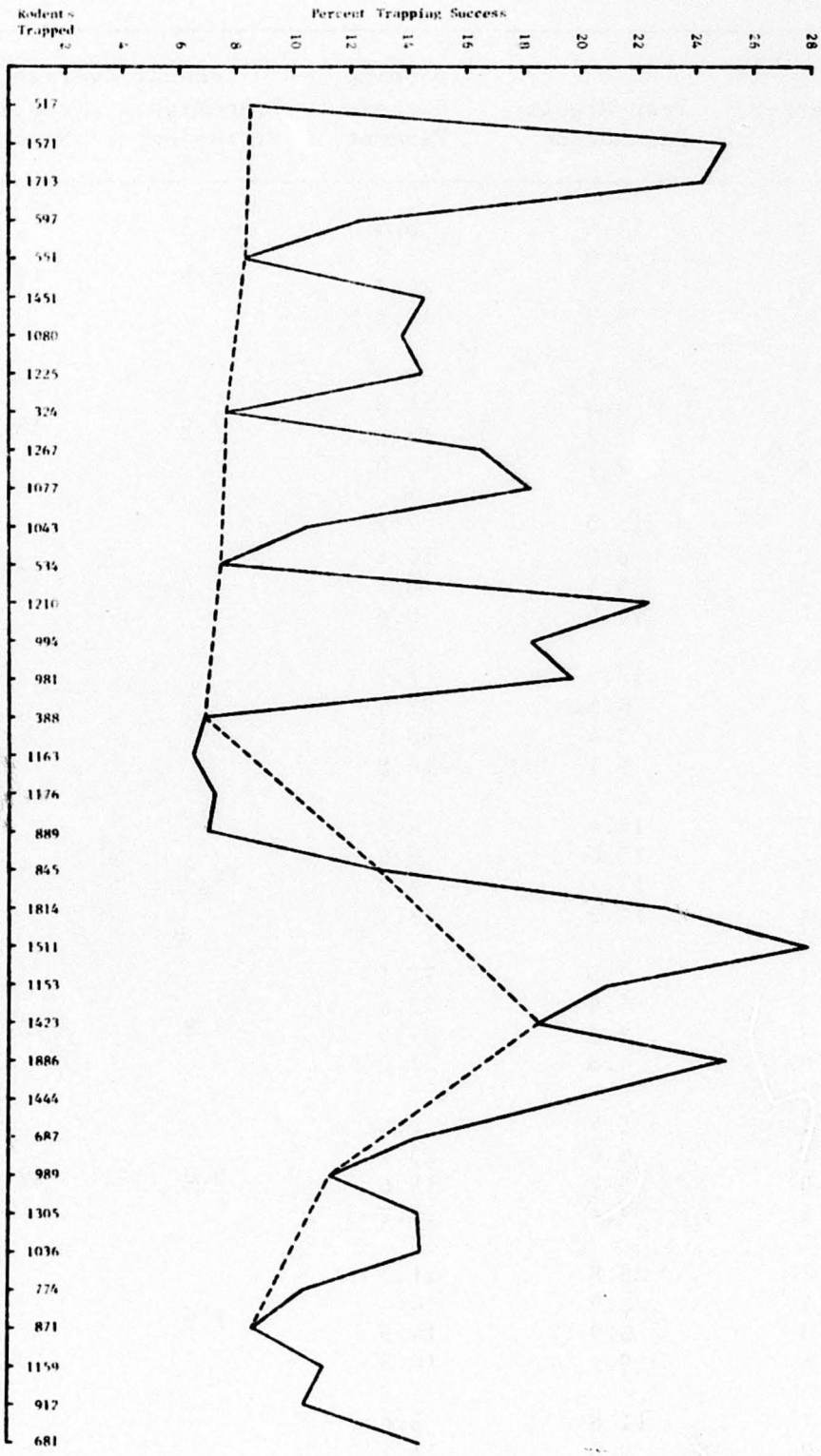


Figure 6. Rodent population fluctuations as revealed by percentage trapping success, by quarter, 1963-1971.

The fidelity and relative frequency of capture of various rodent species within and among the several biotic communities sampled during disease survey rodent trapping from 1963 through 1971 have been analyzed and are summarized in Table 41. The communities are listed in order of decreasing elevation from left to right, with the first four being mountain and/or foothill communities and the latter five being valley floor communities.

In Section C of this table, distribution of trapping effort and success, the total number of rodents captured in populations from which disease survey specimens were obtained and the trapping success are tabulated for each community. The analyses made from this table are based on 37,996 rodents captured in 278,367 trap-nights during the nine-year period.

It will be noted that trapping success or relative rodent abundance, as indicated by the trap-night index, tends to form two major groupings. In the first group of communities where trapping success is highest, including the Juniper Mountain, Juniper Brush, Mixed Brush, Greasewood, Vegetated Dunes and Marsh communities one animal is captured for each 5-8 trap nights of effort. In the second group, where one animal is captured for each 11-18 trap nights, are found the Shadscale-Budsage, Shadscale-Gray Molly-Greasewood and Shadscale-Gray Molly communities. In general, then, greater trapping success is encountered in the mountain and foothill communities than in the valley floor communities. The Vegetated Dunes also supports a relatively high rodent density, but although located on the valley floors, forms an entirely different habitat type than do the other typical valley floor communities.

The species most commonly captured under the standard methods of line live-trapping are listed in Section A of the same table. In each community the most frequently captured rodent species was assigned an arbitrary value of 100. An index figure for each of the other species occurring within the community was calculated by determining the percentage that the number of animals actually trapped of each species was to the number trapped of the most frequently trapped species. Comparisons in Section A can only be made within each community. The frequency index numbers are meaningless when compared among different communities. It will be noted that P. maniculatus was the species most frequently encountered in seven of nine communities, and was second in the other two communities. D. ordii was the most frequently captured species in one community (Vegetated Dunes) while R. megalotis was most common in the other community (Marsh). An indication of the complexity or simplicity of the rodent fauna, the relative monopoly of a community by a single or a few species, and the possibilities of species interaction and ectoparasite exchange can be gained by inspection of the table.

An attempt has been made in Table 42 to assess the relative dominance or competitive success in each community of the four most commonly encountered species. The "competition index" derived from the data in Section A of Table 41 is simply the number of captures of individuals of all other species taken in the community for each 100 captures of the species in question. The dominance of P. maniculatus

Table ... Rodent-biotic community relationships. Figures in Sections A and B represent frequency ratios of some species to most frequently captured species, or of captures in given biotic community to community in which species most frequently captured 1963-1971. See text for explanation.

Section A - Relative frequency of captures of different species within each community.

	Juniper Mountain	Mixed Brush	Juniper Brush	Shadscale-Budsage	Greasewood	Shadscale-[illegible] Molly-Greasewood	Shadscale-[illegible] Gray Molly	Vegetated Dunes	Marsh
Eutamias minimus	*	7		6	69	26	6		
E. dorsalis	4	0.2	0.5						
E. umbrinus	0.2	0.2							
Ammospermophilus leucurus	2	12	19	29	21	32	14	40	2
Spermophilus townsendii		.02				1	1	0.2	
S. variegatus		.01							
Perognathus longimembris	0.2	3	0.1	12	1	3		5	
P. parvus	17	8	1	3	1	1		0.1	
P. formosus	4	17	0.5	4	3	3	10	0.4	
Microdipodops megacephalus		.01				0.1		1	
Dipodomys ordii	2	10	79	78	25	24	28	100	
D. microps	1	8	1	30	7	19	20	13	
Reithrodontomys megalotis	4	9	5	8	9	11	5	10	100
Peromyscus crinitus	2	10	0.1	3	1	1	3	0.1	
P. maniculatus	100	100	100	100	100	100	100	49	94
P. truei	7	0.3	7			0.1		0.02	
Onychomys leucogaster	0.1	0.4	0.7	4		2	1	2	
Neotoma lepida	5	6	12	5	2	1	7	0.05	
N. cinerea	0.04								
Microtus montanus	0.04	0.4		2					37
M. longicaudus	2	2	0.2					0.05	
Mus musculus		0.2	0.1		0.1			0.08	3
Lepus curtatus	0.1	0.1							

Section B - Relative frequency of capture of a species within each of several biotic communities.

Eutamias minimus	19	24			20	100	32	14	
E. dorsalis	100	3	7						
E. umbrinus	100	39							
Ammospermophilus leucurus	12	46	68	45	80	50	18	100	6
Spermophilus townsendii		5				100	53	22	
S. variegatus		100							
Perognathus longimembris	8	57	2	100	19	24		63	
P. parvus	100	32	19	5	5	2		0.3	
P. formosus	32	100	3	9	19	6	20	2	
Microdipodops megacephalus		1				4		100	
Dipodomys ordii	4	14	100	42	33	13	12	86	
D. microps	12	51	6	100	46	48	43	51	
Reithrodontomys megalotis	7	11	3	4	10	6	2	7	100
Peromyscus crinitus	37	100	1	13	9	5	11	0.7	
P. maniculatus	100	67	62	26	65	27	22	21	52
P. truei	100	3	62			0.4		0.2	
Onychomys leucogaster	9	24	42	100		46	34	92	
Neotoma lepida	69	56	100	16	16	4	21	0.3	
N. cinerea	100								
Microtus montanus	0.1	1			7				100
M. longicaudus	100	57	7					1	
Mus musculus		8	5		6			3	100
Lepus curtatus	100	31							

Section C - Distribution of trapping effort and trapping success, by biotic community.

										Total
Traplines set	581	1565	166	54	151	472	53	850	49	3945
Trap nights	33869	102748	11645	4131	9565	39135	4881	69038	3355	278367
% of trapping effort	12.2	36.9	4.2	1.5	3.4	14.1	1.7	24.8	1.2	100.0
Rodents captured	6274	15902	1993	364	1320	3377	278	7968	520	37996
Trap nights/rodents	5.4	6.5	5.8	11.3	7.2	11.6	17.6	8.7	6.5	7.3

Table 42. Relative amount of competition for each of the four most commonly encountered rodent species in each biotic community. The "competition index" figure is the number of captures of individuals of all other species taken in the community for each 100 captures of the species in question.

BIOTIC COMMUNITIES	Juniper Mountain	Mixed Brush	Juniper Brush	Shadscale-Budsage	Greasewood	Shadscale-Gray Molly-Greasewood	Shadscale-Gray Molly	Vegetated Dunes	Marsh
Number of Species Captured	19	22	15	11	13	15	11	17	5
Species with Frequency >5	2	10	5	6	6	6	7	6	3
Competition Index									
Peromyscus maniculatus	54	92	131	185	79	168	115	363	151
Dipodomys ordii	8418	1789	190	266	603	999	675	127	
Ammospermophilus leucurus	7577	1544	1137	874	747	734	1450	463	12850
Eutamias minimus	4248	2786			3047	290	720	3626	
Reithrodontomys megalotis	3646	2087	4136	3600	1903	2238	4550	2269	135

is readily apparent; there is a decided lack of competition in the Juniper Mountain and Greasewood communities and only slightly more in all the other communities except the Vegetated Dunes. D. ordii still exhibits its highest dominance in the Vegetated Dunes community, competing successfully with the deer mice, and offering least in the Juniper Mountain and Mixed Brush. A. leucurus also competes best in the Vegetated Dunes and least well in Juniper Mountain, E. minimus exhibits its best showing in the Shadscale-Gray Molly-Greasewood and is very subordinate in the Juniper Mountain and Vegetated Dunes. R. megalotis really competes well only in the Marsh community.

Section B of Table 41 depicts the relative number of captures of a given species that would be made in each of the communities in which this species occurs. These index numbers are calculated as were those in Section A, except that the numbers actually captured were converted to a theoretical number that would have been captured if equal trapping effort had been put forth in each community and trapping success remained unchanged. The values in this section of the table, in contradistinction to Section A, are valid only for a given species when compared in different communities. Although included, the data for Marsh communities may be insufficient for intercommunity comparison.

It will be noted that eight species reach their maximum frequency of capture in the Juniper Mountain community. Included here is the most commonly captured rodent, P. maniculatus. Of the other most commonly captured animals, D. ordii reaches its highest frequency of capture in the Juniper Brush, A. leucurus in the Vegetated Dunes, E. minimus in the Shadscale-Gray Molly-Greasewood, and R. megalotis in the Marsh community. Apparent habitat preference and community fidelity are also revealed by inspection of Section B.

To this end, a quantitative measurement of the fidelity of the rodent species was attempted and is shown in Table 43. The "fidelity index" is the sum of the relative frequency of capture ratios from Section B for each species times the number of communities in which this species was recorded. The maximum possible value would be 8,100 and the minimum 100. The species have been listed in order of increasing fidelity and have been arbitrarily assigned to categories of relative degrees of fidelity. It will be noted that P. maniculatus, D. microps, and A. leucurus exhibit greatest ubiquity in the habitats in which they are encountered, and Eutamias dorsalis, Microtus montanus and Microdipodops megacephalis are quite restricted. D. ordii also exhibits a relatively low degree of fidelity to any given community.

Although estimates of relative abundance of rodent species are valuable and suffice for most purposes, it is often desirable to be able to express animal numbers in relation to unit area. Reliable data on absolute density is very difficult to obtain and even when secured, is valid only for the particular study area involved and at the point in time the investigation was conducted. By utilizing a combination of absolute density data gathered in several special studies conducted during past years in two different biotic communities

Table 43. Relative ubiquity of rodent species among various habitat types as revealed by a quantitative measurement of fidelity, 1963-1971.

Species	Number of Communities Frequented	Fidelity Index*	Degree of Fidelity
Peromyscus maniculatus	9	3978	
Ammospermophilus leucurus	9	3825	Low
Dipodomys microps	8	2856	
Dipodomys ordii	8	2432	
Onychomys leucogaster	7	2429	
Neotoma lepida	8	2258	Moderately Low
Perognathus longimembris	7	1911	
Perognathus formosus	8	1528	
Reithrodontomys megalotis	9	1350	
Peromyscus crinitus	8	1414	Moderately High
Eutamias minimus	6	1254	
Perognathus parvus	7	1143	
Peromyscus truei	5	828	
Microtus longicaudus	4	660	
Microtus montanus	4	432	High
Eutamias dorsalis	3	330	
Microdipodops megacephalis	3	315	

*Maximum possible value, 8,100. Minimum possible value, 100.

Table 44. Estimates of average rodent density by biotic community.

Community	Average Trapping Success	Trap Nights Per Animal	Rodents Per Acre
Juniper Mountain	18.5%	5.4	17-26
Juniper Brush	17.1%	5.8	15-22
Mixed Brush	15.5%	6.5	14-20
Greasewood	13.8%	7.2	12-17
Vegetated Dunes	11.5%	8.7	10-15
Shadscale-Budsage	8.8%	11.3	7-11
Shadscale-Gray Molly-Greasewood	8.6%	11.6	7-11
Shadscale-Gray Molly	5.7%	17.6	5-7

and relative abundance figures obtained during eight years of trapping as illustrated earlier in this section, it has been possible to arrive at estimates of the numbers of rodents per acre in each of the major biotic communities. These estimates, shown in Table 44 are the average number per acre derived from trapping in all seasons over a nine-year period during which time populations have been at high, low and intermediate levels; thus, at any one given sampling period the density encountered in the community in question could be much lower or in excess of the average density here tabulated. Limited as this data may be in application, it does help to place the typical rodent populations we are dealing with in the study area in better perspective.

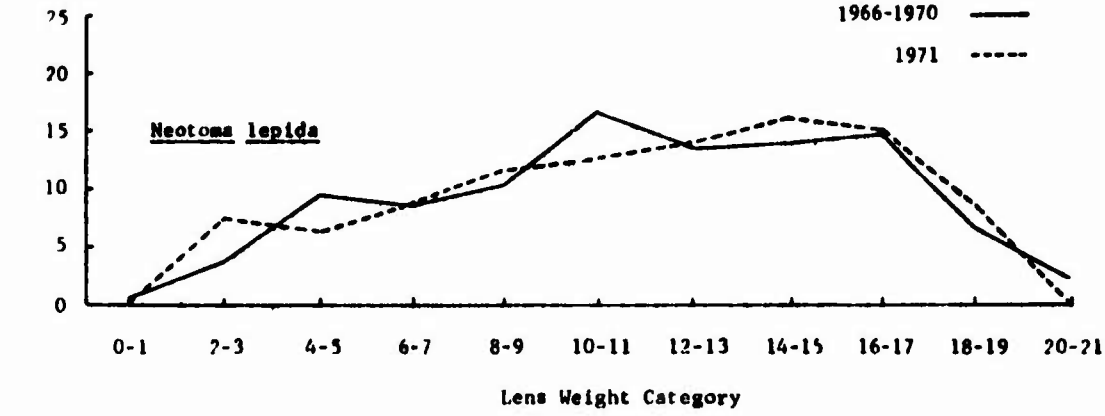
Age structure and Reproductive Periodicity of Rodent Populations as Indicated by Lens Weight Analysis

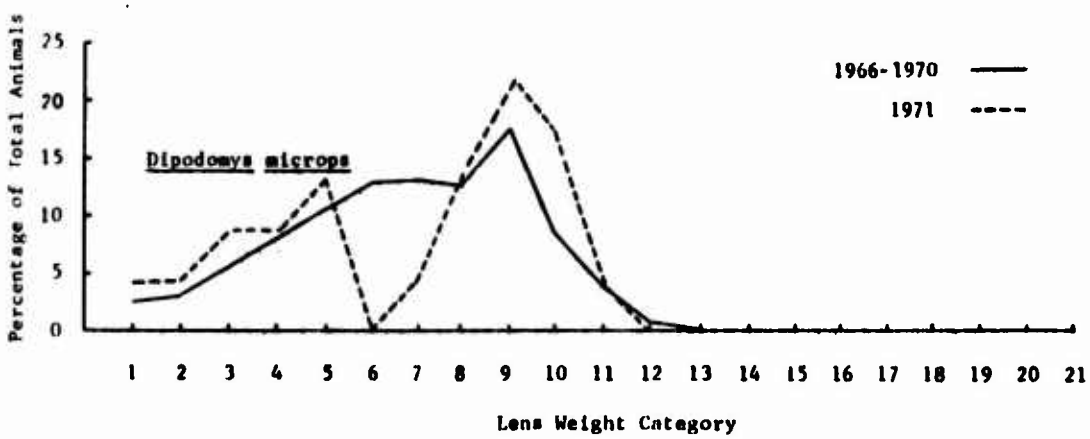
Investigations of the correlation between age and rodent eye-lens weight were begun in 1966. Over the ensuing years as known-age animals became available correlations were made and curves constructed which allowed reliable prediction of age from the dried lens weights of five common species of rodents. These curves and their equations were published in the 1969 Annual Summary Review, Ecology and Epizoology Research, University of Utah. To date, known-age lenses have been obtained from 221 D. ordii, 52 D. microps, 153 N. lepida, 29 A. leucurus and 281 P. maniculatus. Correlation of age with lens weight is now available up to the age of 559 days for D. ordii, 447 days for D. microps, 894 days for N. lepida, 234 days for A. leucurus, and 757 days for P. maniculatus.

Lens weights are sorted into classes by one, two or four milligram increments depending upon the species. The ages associated with each of these categories for each species are noted in the tables showing the frequency distribution of lens weights.

In regard to techniques, lenses are prepared in the following manner: An eyeball is removed immediately after the animal is sacrificed by ether asphyxiation and then fixed in 10% formalin solution for from three to seven days. The lens is then removed and dried on a spot-plate in a convection-type hot-air oven at 100°C for six days after which it is immediately weighed on an Ainsworth Type 24N analytical balance.

Lens weights were taken from all specimens of five rodent species which were processed for epizoological surveillance and this data was analyzed to determine the age structure of the populations of each species over the year as it varied by month. Comparison with similar data from previous years allowed evaluation of the relative timing of the onset of breeding and peak periods of production as well as relative population growth. These comparisons and analyses are based on the following numbers of individual lens weights collected from 1966-71 inclusive with the exception of the data for deer mice which is from 1968-71: 624 N. lepida, 667 D. microps, 1,451 A. leucurus, 2,744 D. ordii, and 7,412 P. maniculatus. The frequency distributions of dried lens weights for each species are summarized in Tables 45 to 49 and graphically illustrated in Figures 7 and 8.





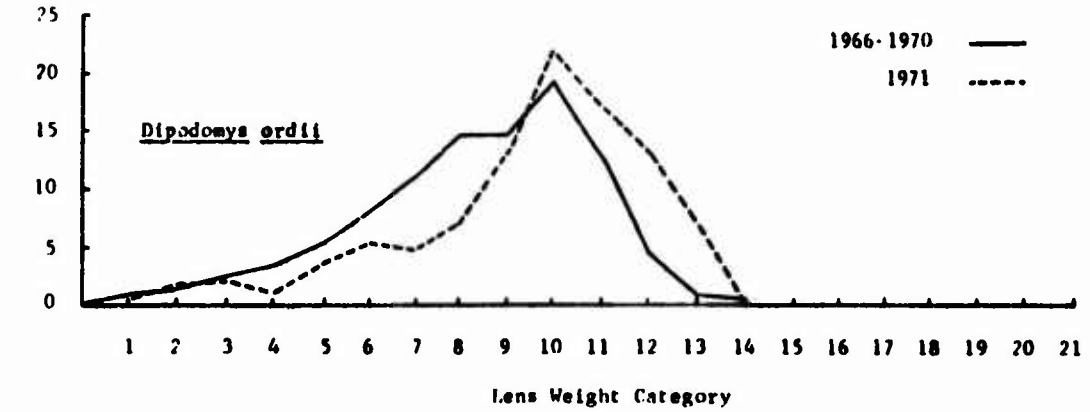


Figure 7. Frequency distributions of dried lens weights of Dipodomys ordii, Dipodomys microps, and Neotoma lepida captured from the wild, 1966-1971.

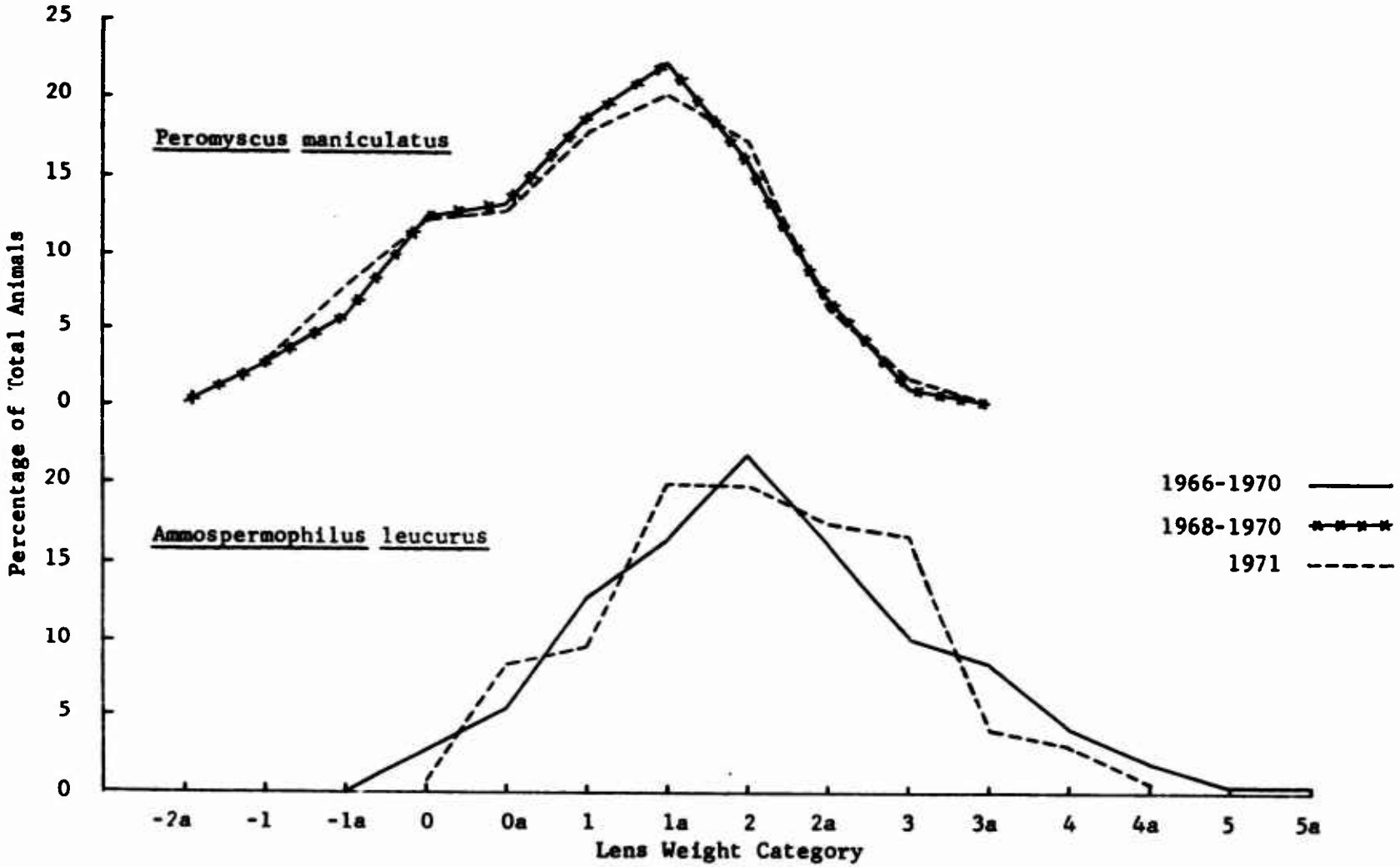


Figure 8. Frequency distributions of dried lens weights of Ammospermophilus leucurus and Peromyscus maniculatus captured from the wild, 1966-1970, 1968-1970, and 1971 respectively.

Table 45. Frequency distributions of dried lens weight of Ammospermophilus leucurus captured from the wild, 1966-1971.

Lens Weight Category	Lens Weight in mg.	Age in Days	1966-1970 Number of Individuals	1966-1970 Percentage	1966-1970 Cumulative Percentage	1971 Number of Individuals	1971 Percentage
-1a	4.0- 4.9	38- 49	1	0.1	0.1		
0	5.0- 5.9	50- 63	35	2.7	2.8	1	0.6
0a	6.0- 6.9	64- 82	69	5.4	8.2	14	8.4
1	7.0- 7.9	83-109	162	12.6	20.8	16	9.6
1a	8.0- 8.9	110-153	211	16.4	37.2	33	19.8
2	9.0- 9.9	154-233	277	21.6	58.8	33	19.8
2a	10.0-10.9	234-426	208	16.2	75.0	29	17.4
3	11.0-11.9	427+	129	10.1	85.1	28	16.8
3a	12.0-12.9		108	8.5	93.6	7	4.2
4	13.0-13.9		53	4.1	97.7	5	3.0
4a	14.0-14.9		25	1.9	99.6	1	0.6
5	15.0-15.9		3	0.2	99.8		
5a	16.0-16.9		3	0.2	100.0		
	Totals		1284			167	

Table 46. Frequency distributions of dried lens weights of Dipodomys ordii captured from the wild, 1966-1971.

Lens Weight Category	Lens Weight in mg.	Age in Days ♂	Age in Days ♀	1966-1970 Number of Individuals	1966-1970 Percentage	1966-1970 Cumulative Percentage	1971 Number of Individuals	1971 Percentage
0	5.0- 6.9			2	0.1	0.1		
1	7.0- 8.9	23- 29	23- 30	24	0.9	1.0	1	0.5
2	9.0-10.9	30- 39	31- 40	37	1.4	2.4	3	1.6
3	11.0-12.9	40- 49	41- 51	72	2.8	5.2	4	2.1
4	13.0-14.9	50- 63	52- 66	89	3.5	8.7	2	1.1
5	15.0-16.9	64- 79	67- 84	142	5.5	14.2	7	3.7
6	17.0-18.9	80-101	85-110	207	8.1	22.3	10	5.3
7	19.0-20.9	102-132	111-147	283	11.2	33.5	9	4.8
8	21.0-22.9	133-178	148-206	376	14.7	48.2	13	6.9
9	23.0-24.9	179-256	207-315	377	14.7	62.9	26	13.9
10	25.0-26.9	257-414	316-583	480	18.9	81.8	41	21.9
11	27.0-28.9	415+	584+	329	12.8	94.6	33	17.6
12	29.0-30.9			115	4.5	99.1	25	13.4
13	31.0-32.9			19	0.7	99.8	13	6.9
14	33.0-34.9			5	0.2	100.0		
	Totals			2557			187	

Table 47. Frequency distributions of dried lens weights of Dipodomys microps captured from the wild, 1966-1971.

Lens Weight Category	Lens Weight in mg.	Age in Days ♂	Age in Days ♀	1966-1970 Number of Individuals	1966-1970 Percentage	1966-1970 Cumulative Percentage	1971 Number of Individuals	1971 Percentage
1	7.0- 8.9	24- 33	30- 38	17	2.6	2.6	1	4.3
2	9.0-10.9	34- 45	39- 49	20	3.1	5.7	1	4.3
3	11.0-12.9	46- 60	50- 64	35	5.4	11.1	2	8.7
4	13.0-14.9	61- 80	65- 85	53	8.2	19.3	2	8.7
5	15.0-16.9	81-107	86-117	69	10.7	30.0	3	13.0
6	17.0-18.9	108-148	118-172	83	12.9	42.9	0	0.0
7	19.0-20.9	149-218	173-288	84	13.1	56.0	1	4.3
8	21.0-22.9	219-363	289-709	82	12.7	68.7	3	13.0
9	23.0-24.9	364-846	710+	113	17.6	86.3	5	21.7
10	25.0-26.9	847+		55	8.5	94.8	4	17.4
11	27.0-28.9			27	4.2	99.0	1	4.3
12	29.0-30.9			5	0.8	99.8		
13	31.0-32.9			0	0.0	99.8		
14	33.0-34.9			1	0.2	100.0		
	Totals			644			23	

Table 48. Frequency distributions of dried lens weights of Neotoma lepida captured from the wild, 1966-1971.

Lens Weight Category	Lens Weight in mg.	Age in Days ♂	Age in Days ♀	1966-1970 Number of Individuals	1966-1970 Percentage	1966-1970 Cumulative Percentage	1971 Number of Individuals	1971 Percentage
0- 1	5.0- 8.9			3	0.6	0.6		
2- 3	9.0-12.9	- 45	- 47	20	3.8	4.4	7	7.4
4- 5	13.0-16.9	46- 64	48- 68	50	9.4	13.8	6	6.4
6- 7	17.0-20.9	65- 89	69- 94	45	8.5	22.3	8	8.5
8- 9	21.0-24.9	90-122	95-129	55	10.4	32.7	11	11.7
10-11	25.0-28.9	123-170	130-180	88	16.6	49.3	12	12.7
12-13	29.0-32.9	171-248	181-261	72	13.6	62.9	13	13.8
14-15	33.0-36.9	249-394	262-413	73	13.7	76.6	15	16.0
16-17	37.0-40.9	395-781	414-806	78	14.7	91.3	14	14.9
18-19	41.0-44.9	782+	807+	35	6.6	97.9	8	8.5
20-21	45.0-48.9			11	2.1	100.0		
	Totals			530			94	

Table 49. Frequency distributions of dried lens weight of Peromyscus maniculatus captured from the wild, 1968-1971.

Lens Weight Category	Lens Weight in mg.	Age in Days ♂	Age in Days ♀	1968-1970 Number of Individuals	1968-1970 Percentage	1968-1970 Cumulative Percentage	1971 Number of Individuals	1971 Percentage
-2a	2.0- 2.9	10- 17	11- 19	6	0.1	0.1	2	0.1
-1	3.0- 3.9	18- 27	20- 29	154	2.7	2.8	45	2.7
-1a	4.0- 4.9	28- 39	30- 41	335	5.8	8.6	131	7.9
0	5.0- 5.9	40- 55	42- 57	712	12.3	20.9	205	12.4
0a	6.0- 6.9	56- 78	58- 81	798	13.8	34.7	214	13.0
1	7.0- 7.9	79-114	82-117	1078	18.7	53.4	293	17.7
1a	8.0- 8.9	115-181	118-184	1277	22.2	75.6	333	20.2
2	9.0- 9.9	182-347	185-345	930	16.1	91.7	288	17.4
2a	10.0-10.9	348+	346+	404	7.0	98.7	111	6.7
3	11.0-11.9			65	1.1	99.8	26	1.6
3a	12.0-12.9			3	0.1	100.0	2	0.1
	Totals			5762			1650	

Young A. leucurus began to appear in the sampled population during May of 1970 and 1971 indicating a birth date in February and March and were represented through August. This is a normal situation, but is in contrast to 1969 when there was a delayed and shortened breeding period for this species with the youngest age class being captured only during June and July. Other indicators including the reduced number of sightings of these squirrels in the field and the fact that the fewest number were captured in traps set for routine surveillance activities since prior to 1963, substantiate that 1969 was not a successful year for these animals. The lens weight frequency distribution peaked in Class 2a in 1969 rather than in Class 2 as in previous years indicating an older population to which little recruitment had been added. The median age of the squirrels collected was 263 days as compared to the 203 day median during 1966-68. That during 1970 and 1971 the squirrels were able to make a strong comeback is evidenced by the early and prolonged breeding season probably accompanied by increased litter size and multiple litter production, their greater relative and absolute abundance in collections, and the youth of the sampled population with the lens frequency distribution peaking in Class 1a in 1970 and between 1a and 2 in 1971. The median age for 1970 was 167 days, the youngest A. leucurus population we have encountered, and the 1971 median age was 207 days the same as the 1966-1970 median.

Populations of D. ordii have not fared well in the general study area for the last three years. Both the relative and absolute abundance of these animals have been on a modest decline for a longer period of time; an approximate 20% reduction in the number of these kangaroo rats trapped annually in routine surveillance has occurred when the 1968-70 period is compared with the 1963-67 period. The 1971 total trapped was approximatly 40% less than in 1970 showing even a greater reduction. The 1971 total of 247 is a very significant reduction from the 1970 total of 415 and the 1969 and 1968 totals of 677 and 701. All of these are even greater when compared to the 838 taken in 1964 and 922 in 1966. Over all these years trapping effort has been relatively uniform in intensity and timing.

Lens weight analysis have reflected these changes in abundance. The lens weight class most frequently encountered has advanced by one class per year from 1966 through 1970 then regressed one class in 1971. In 1966 the curve peaked in Class 8, in 1968 in Class 9, in 1969 in Class 10, in 1970 in Class 11, and in 1971 back to Class 10. The ages of animals in Class 8 range from 133-206 days while those in Class 11 are at least 415 days of age. The median age of the annual samples has also increased from 162, 163 and 176 days in 1966-1968 respectively to 312 days in 1969, 304 days in 1970, to 360 in 1971, indicating a population which is still top-heavy with older individuals, but is starting to expand. Analysis of the monthly distribution curves verify this by showing an early start and late termination of breeding during the year as opposed to 1970 when there was a late start and early termination.

For approximately 10 years, the D. microps population has been gradually declining. The cause of this decline is unknown but has

been the subject of past investigations and speculation in previous Annual Summary Reviews, Ecology and Epizoology Research, University of Utah. With fewer than 100 specimens available for lens weight analysis during each of the past four years, the validity of conculusions drawn from this data is not strong. The general characteristics of a declining population, i.e., with age structure tending strongly to older individuals, are evident, however. The small sample size makes the significance of median age questionable but for the period 1966-71, this value has been 136, 253, 110, 161, 176 and 430 days. With only 23 individuals available during 1971, this species has become rare in the Dugway area. Two-thirds of those used were more than 14 months of age.

The small sample size of N. lepida prevents detailed analysis of the population age structure. No particular long-term trends toward increasing or decreasing populations are evident with this species; their restricted distribution is the primary reason for the relatively small numbers sampled. Analysis of the lens weight distribution curves shows that wood rats, like most other species of rodents, did not enjoy a productive year during 1970 or 1971 with the age structure exhibiting a greater preponderance of old animals than in previous years, but not as high as in 1970. More young animals were sampled in 1971 indicating improving population conditions. The median age of wood rats sampled during 1971 was 201 days compared to 264 days in 1970 and 184 days during the 1966-70 period.

The long-term trend in the P. maniculatus population has been one of increasing relative and absolute abundance. Whereas from 1963-67 the annual average number of these deer mice captured was about 1,300, this has increased to 2,700 during the 1968-71 period and the contribution of this species to the total number of rodents trapped has risen from 30% to 55%. Analysis of lens weight distribution curves shows that for each of the four years studied breeding has taken place virtually year round with main periods of activity from February to May and September. The distributions show little difference among the years studied with peaks occurring in Class 1a, the age limits of which are 115-184 days, in each of the four years. A somewhat older population was sampled during 1969 than in 1968 but during 1970 the age structure reverted to 1968 levels, and 1971 back to older animals similar to 1969. The median age during 1968, 1969, 1970 and 1971 was calculated at 87, 115, 88 and 107 days respectively.

Perhaps one of the most important findings which has resulted from these age structure studies of wild mammal populations is confirmation and quantitation of the assumed rapid turnover of animals. Among the antelope squirrels, wood rats and two species of kangaroo rats, 50% of the populations on an annual basis are less than 6-7 months of age while among the deer mice half are less than 3 months old. The importance of this rapid turnover in relation to disease ecology is at once apparent.

PRODUCTION OF NATIVE MAMMALS

Breeding colonies of eight native rodent species were maintained during 1971 with a net production of 2,793 animals. This figure is a slight reduction from the 3,079 produced during 1970 and reflects reduced requirements for such animals. As will be noted from the summary in Table 50 productivity of the individual species has remained high and mortality rates have decreased.

Table 50. Summary of small mammal production for 1971.

Species	Basic Number of Breeding Pairs	Litters Produced	Total Animals Born	Mort.	% Mort.	Net Prod.	Average Litter Size	Avg. Number Animals Prod. Per Month
Peromyscus maniculatus	16	138	872	43	4.9	829	6.3	69
P. crinitus	16	122	283	10	3.5	273	2.3	23
P. truei	16	100	354	3	0.8	351	3.5	30
Reithrodontomys megalotis	16	119	548	7	1.3	541	4.6	46
Microtus montanus	16	94	405	75	18.5	330	4.3	34
Onychomys leucogaster	16	68	253	6	2.4	247	3.7	21
Neotoma lepida	12	47	141	12	8.5	129	3.0	11
Dipodomys ordii	variable	38	109	16	14.7	93	2.9	--
Totals	108	726	2965	172	6.8	2793	---	234